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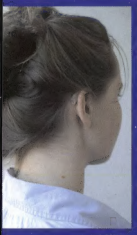

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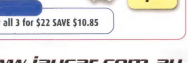

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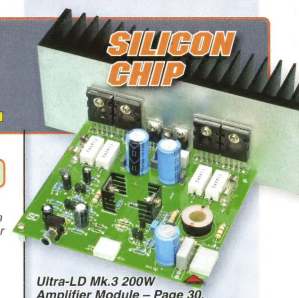

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Publisher's Letter

The quest for ultra-low distortion

This month, we present the first article on the Ultra-LD Mk.3 amplifier module. This is the second time we have revisited this class-AB amplifier design and it's almost getting monotonous, as we announce even lower distortion. Exceedingly low! In these days of iPODs and MP3 players, why do we bother?

The reason is that those sound sources are so mediocre. Why put up with mediocrity? The same comment can be made of the vast majority of home-theatre systems and indeed, virtually any sound source that most people listen to. Compared to where we were with high-fidelity sound systems based on CD players 25 years ago, we have gone backwards. Furthermore, it can safely be said that the vast majority of people under the age of 30 probably have never experienced a good hifi sound system. If they have, it was probably years ago while they were still living with their parents.

We at SILICON CHIP, on the other hand, believe that the best quality sound is still worth striving for. We also have better tools and design methods to help us get there than we did years ago. Our benchmark is the standard of performance available from the best CD players available today, such as the Marantz CD player reviewed in last month's issue. So in designing a no-holds-barred amplifier, our task is to produce something that does not degrade the sound quality of such a CD player in any way. Or for that matter, the sound quality of a premium Blu-Ray DVD player.

Ideally, this means that its total harmonic distortion across the entire audible spectrum up to 20,000Hz must be less than .0015% and its signal-to-noise ratio should be better than -110dB. If we get more distortion or more low-level noise, we are degrading the signal quality. It turns out to be a very difficult task to achieve such a standard. Indeed, home-theatre equipment, from even the best brands, is hard-pressed to achieve .01% harmonic distortion – about 10 times worse. And the typical home-theatre system with class-D amplifiers is a good deal worse again.

Our 20W Class-A Amplifier has been our best attempt to date and its distortion is far below that of the best CD and Blu-ray DVD players, for frequencies below 10kHz at least. We have always aimed for the same standard with our more powerful class-AB designs and that is a much more difficult task. But with the Ultra-LD Mk3 amplifier module we have come tantalisingly close, as readers who like to closely compare performance graphs will attest (the relevant graphs for our 20W Class-A amplifier were featured in the May 2007 issue). The difference is that the Ultra-LD module is a great deal more powerful than the class-A design.

Significantly, the new module typically has half the harmonic distortion of the module it supersedes. And while we are very pleased to be able to present it, we have not left all those people who built the previous module in the lurch. We intend to bring out a small adaptor PCB which will bring it up to the same standard.

Is this the ultimate in amplifier design? In the true sense of the word, it is but only for now. Who knows what new devices and new techniques may bring in the future. In the meantime, our challenge is to produce a complete integrated amplifier featuring the new module and with facilities for analog and digital sound sources. If the development of the new Ultra-LD amplifier module is anything to go by, that could take some time. Stay tuned.

Leo Simpson

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MAILBAG

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Anti-glare glasses are useless at night

I noted your comments on glare from headlights. Anti-glare glasses are useless in this scenario. Night vision is mainly processed by the rods in the retina. They are the receptors that respond to low-intensity light. Unfortunately they also stay refractory for 30 minutes after exposure, ie, they take 30 minutes to recharge before being able to fire again at low intensity.

Rods also do not respond to light in the red/orange wavelengths but cones do and they have a short refractory period but require higher intensity light to activate. That is why submarines and night cockpits are illuminated with red light to allow the rods to respond to other low intensity (night) light sources.

Yellow driving glasses sit on the edge wavelength of rod responsiveness, ie, headlights will just begin to depolarise the receptors but will not make them as refractory for as long as white light and will make it easier to see detail in the situation where there are oncoming headlights. Unfortunately, they will also change the perceived colour of stop lights etc.

This is known to car manufacturers as they used to make yellow fog lights to illuminate the side of the road and not blind other drivers, unlike nowadays when fog lights are used as a status symbol, often illegally.

Early cataract formation will further refract light and make it harder to see in the context of oncoming headlights but protecting the responsiveness of your rods will lessen the risk of an accident due to temporary blinding.

Name & address supplied but withheld at writer's request.

No need to wait for Thorium reactors

Luke Biddle (Mailbag, May 2011) is right to propose the use of Thorium in new designs of nuclear reactors but his enthusiasm might need some tempering.

As Luke says, there is no expensive isotopic separation required. The only isotope of Thorium to occur naturally is Thorium-232. It is slightly radioactive with a half-life of 14.05 billion years; much longer than that of the naturally occurring isotopes of Uranium, which may account for its greater abundance. The mantles in portable gas camping lamps are made from Thorium dioxide, a ceramic that glows brilliant white when heated and with the highest melting point of all oxides: 3300°C.

Many websites advocating Thorium as a nuclear fuel do not make it clear that the various reactor designs are still very much at the research stage. They also do not indicate clearly that Thorium, unlike that well-known isotope of Uranium, U-235, is not itself fissile, an essential property for an element to become a nuclear fuel. An atom of Thorium-232 must first absorb a neutron to become the Uranium isotope U-233, which is fissile.

www.ga.gov.au/minerals/mineral-resources/Thorium.html offers a good summary of the situation. It also confirms that there are large amounts in Australia in the form of Monazite sands in Queensland, NSW and WA.

To kick-start a nuclear reactor containing Thorium, the Thorium has to be placed in the reactor as a blanket around a fuel load of a fissile isotope, such as U-235 or U-233 and remain there for some months during normal reactor operation so that the absorption of the neutrons and conversion from Th-232 to U-233 can occur. Then, if it is in a current design of water-cooled reactor, the blanket material has to be removed, the newly-created U-233 is separated from the unconverted Thorium, then the U-233 is fabricated into new fuel rods to then be used as nuclear fuel.

Note that U-233, like U-235 and Plutonium-239, can be used to make a nuclear weapon. Luke's claim in that respect is not correct.

Why medical devices are so expensive

In the Mailbag pages of your June 2011 issue, a reader wrote wondering why hearing aids are similar in price to vastly more complicated consumer equipment, such as a laptop.

In general, medical equipment is priced between two and 10 times the consumer equivalent. The three main reasons are quality, safeguards and regulation. Medical devices (including hearing aids), should be compared to industrial electronics rather than consumer electronics. They are designed to be used day and night, with as little downtime as possible, typically for a lifespan of about 10 years.

If a medical device is used in intensive care, operating theatre or on high-risk patients, it must have alarms, interlocks and fail-safe systems to protect patients. Lastly, for a medical device to be sold legally in Australia, it must meet very stringent regulations. For instance, to manufacture a hearing aid, a medical device company must certify every building, room, measurement, process, machine and material involved, show that the device is safe and effective and be accountable for any death or injuries it causes. It all depends on what purpose a device is sold for: $100 at a pharmacy buys you a heart-rate monitor for jogging. Similar technology sold to a hospital specifically for diagnosis or therapy might cost $1000.

Michael Smith, Technical Officer, Clinical Support,
Flinders Biomedical Engineering,
Flinders Medical Centre,
Bedford Park, SA.

Thorium advocates concentrate on the possibility of the use of liquid-fuelled, high-temperature reactor designs where the Thorium is present as a fluoride salt. This design is known as the Liquid Fluoride Thorium Reactor (LFTR). As with the above design, the reactor still requires a start-up fuel load of fissile Uranium, usually U-233, present in columns as fuel in the form of Uranium fluoride within the Thorium fluoride salt blanket.

All of this material, both fuel and blanket, becomes liquid at an operational temperature of some 600°C. The fuel and blanket do not mix, being contained in separate ceramic tubes.

The Thorium converted to U-233 is subsequently extracted from the blanket by a jet of fluorine gas, then cleaned up outside the core and re-injected. Again, as with present reactor designs, there is the possibility of diversion of the extracted U-233 into weapons production. On the matter of fission product waste production: while the mix of fission products may have somewhat shorter half-lives than that extracted from conventional U-235/U-238 fuel, it is still a nasty mix that has to be properly processed and stored as nuclear waste.

I am not sure what Luke means where he says "radioactive waste can be fed back into the process to fuel the system . . .". The only thing that is fed back in is the absolutely necessary U-233 fissile fuel. It is indeed radioactive but is not "radioactive waste" in the usually accepted sense.

Standard-8 film could have had sound added at processing

With respect to the article on the Projector Speed Control (SILICON CHIP, April 2011), I noticed the comment in the panel on page 64: "Note standard film did not include sound".

I thought this was wrong as my aunty was a camera buff back in the sixties when I was in high school. She had a clockwork dual-8 movie camera which would not have had sound but the finished film was magnetic striped; not sure at processing or afterwards. She had a Eumig sound projector.

I thought my memory might be slipping so checked the web. If you go to **www.8mm16mmfilmcollectibles.com** you will find a listing of standard 8mm projectors (and super-8 and 16mm), many with sound and for sale. From this, the film and cameras may not have had the capabilities at that stage but the projectors could record/play from a magnetic stripe.

Stephen Rawlins,
Peterborough, SA.

Comment: standard-8 film did not have the facility for sound since the camera did not provide an audio record function with a light exposure soundtrack on the film. Sound, as you suggest, would have been separately recorded.

The comments relating to sound in the article would apply to any film with sound whether using magnetic tape or modulated film exposure.

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Mailbag: continued

The claim that "One tonne of [Thorium] produces as much power as 200 tonnes of Uranium . . ." is only correct in the sense that current US policy is not to reprocess spent fuel. Only a small part of the U-238 in the spent fuel is used as fuel on the first pass through a conventional reactor, the rest being either still present as U-238 or converted to various isotopes of Plutonium, all of which are useful as fissile fuels but by a US policy decision are not recycled.

This point becomes important when it is realised that there are a number of so-called Generation IV reactor designs, all based on the same high temperature/non-pressurised operation model as the LFTR, that do indeed consume the U-238 as fuel. The Integral Fast Reactor (IFR) design, for example, which can use any of the nuclear fuels, including Thorium, is also similarly supposedly incapable of a meltdown and is able to extract all the energy of U235/U238.

If the IFR is commercialised, then the oft-quoted one tonne versus 200 tonnes advantage of Thorium disappears because the U238 is then used up rather than removed as spent fuel.

In pointing out these errors, I am not attempting to bury Luke's enthusiasm for the Thorium reactor; quite the contrary. By all means, advocate a particular reactor design – and the Thorium concept has a great deal going for it – but do not potentially destroy a very good concept in its infancy with statements that are wrong.

For example, to suggest that the LFTR cannot be used to produce weapons is simply wrong – this reac-

Cassette recorders not needed

In the "Ask Silicon Chip" pages of the June 2011 issue, B. P. wrote that he wanted a substitute for a cassette recorder.

Our church abandoned the option of recording services on tape nearly five years ago. We were using a laptop and projector at the time to have our service orders projected at the front of the church. I then went the one step further and tested the option of recording the service on the same machine with great success.

We have been recording the services since 2006 and editing them. I start the recording up to 30 minutes before the service to avoid interference with the PowerPoint service order.

At the end of the service I save the total recording and edit it. This involves trimming off pre-service and post-service sound and this then becomes the final saved file. I also trim out the sermon and save this separately and this is emailed to the "shut-ins".

This is all done in MP3 format using a mono low-quality setting to reduce file size. As we are all aware, these can be replayed on any number of devices.

We use "Wavepad" for the editing but there are any number of programs available (see the USB Stereo Recorder article in the June 2011 issue of Silicon Chip). It takes less than 10 minutes to do all the editing and multiple copies are very easy to make.

Ray Saegenschnitter, VK3UCB, Huntly, Vic.

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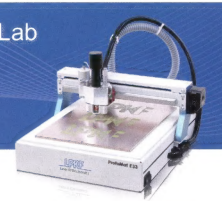
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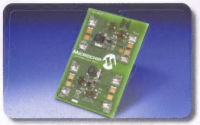

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Comment on XLR connectors in USB recording interface

I refer to the article on the USB recording/playback interface project in the June 2011 issue. I may be wrong but haven't you got the sex of the XLR connectors wrong?

As I remember it, the convention was SOURCE is MALE. This applied to any TV or broadcast studio I ever worked on in an installation capacity. This convention applied to any "professional" equipment I had anything to do with.

Unfortunately, changing the sex of your connectors is a major task as you can't just fit a female connector as pin 1 (ground or earth) will finish up on the wrong side. You probably have to live with it now and use a Female/Female adapter cable, particularly if a balanced microphone is already fitted with a cable.

If not it won't really matter as a cable will have to be made or purchased and can be organised to suit the connectors used.

Robert Rayner,
Willow Vale, Qld.

Comment: thanks for the feedback. With hindsight we should have used female XLR connectors for the microphone inputs on the USB Recording/Playback Interface. However, this mistake is actually not difficult to correct.

Female XLR connectors can be fitted to the front panel and the connections between pins 3 & 1 of each connector "swapped over" between the connector's rear lugs and the pads on the PC board – instead of passing straight down. This can be done fairly easily if short lengths of insulated hookup wire are used to make these connections, ensuring that there will be no accidental shorts.

tor design, while not very efficient at it, can also produce Plutonium as well as U-233. Both are used in nuclear weapons.

But let's be clear in our thinking. The current models of pressurised water reactors (PWRs) are very safe and intrinsically safer than the old Fukushima plant design. They are far less polluting than coal-fired plants and deliver real, base-load power. Unlike Generation IV designs, of which Luke's favoured LFTR reactor is but one, they are commercially available now, as opposed to at least 20-30 years into the future.

Resources:

(1) **www.world-nuclear.org/info/inf62.html** is an authoritative source. (2) There is a very good article and excellent discussion, contributed to by some of the world's leading nuclear power experts, on the pros and cons of the Thorium reactor at **http://bravenewclimate.com/2009/12/17/lftr-in-australia/** There are also many excellent blogs on this site on the IFR, other reactor designs and energy issues in general. (3) Kirk Sorensen's YouTube video at **http://www.youtube.com/watch?v=N2vzotsvvkw** provides both an excellent perspective on mankind's need for energy as well as his own enthusiastic support for the Thorium reactor concept.

Paul Miskelly
Mittagong, NSW.

Phone line polarity checker does work

I read your article regarding the line polarity and the tester (SILICON CHIP, May 2011) and thought, "Yeah right!" The devices should comply with Telstra Service Interface Specification (TSIS) for ADSL Access.

Then recently I was remote testing a DSL install (from the DSLAM) and the service would not meet our minimum SNR Margin of 8dB. Before messing with line profiles or logging a fault with Telstra, I got our field engineer to swap the A and B wires.

Wow! It now gave 14dB SNR margin, I'm a convert! By the way, the modem was a Siemens 4200.

Rod Beech,
Fernvale, Qld.

Grid-connect inverters cannot be used in stand-alone mode

In the Mailbag pages in the April 2011 issue, you commented in your reply to the author of the "Solar Panel Generation Report" that you were investigating how a grid-connect inverter might be used as a stand-alone inverter in the event of a mains failure. "With extreme difficulty . . . " might be a suitable answer! As a TAFE lecturer who is delivering the "Grid-Connect Installer" course in Adelaide, I would like to pass on the following information.

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Grid-connect inverters receive DC from the solar array (or wind generator or small hydro system) and use it to generate an AC waveform. While the grid is available, the inverter tracks the grid sinewave and generates its own sinewave at a fraction of a volt above the grid voltage and a degree or so ahead of the grid waveform. This forces energy to flow into the grid.

The first problem with stand-alone operation of a grid-connect unit is that in the absence of a grid sinewave, most inverters will lose their synchronising AC reference signal and "free-run" well away from the 230V, 50Hz ideal.

The second problem with stand-alone operation is that grid connect inverters MUST have several features called "anti-islanding" built into them or connected to them, if they are to conform to the Australian Standard covering them (AS4777 Parts 1, 2 & 3). "Islanding" is defined as the continued operation of the inverter if the grid is disconnected or the inverter output goes beyond the limits defined by the inverter manufacturer for proper operation for paralleling with the grid.

Anti-islanding systems prevent inverters from continuing to operate on-line or off-line if the mains from the grid is out of normal limits for voltage or frequency, or is just not available. This may be due to a generation or distribution fault, or perhaps due to the grid being cut so the supply authority's workers can safely work on the system. If an inverter continued to run on-line under the latter condition and back-fed into the grid, it could prove fatal to a line worker.

Also, the inverter would attempt to power the loads in other premises that were still on the disconnected or failed grid and would promptly overload and shut down. Even in light-load conditions and with a number of other inverters back-feeding into the grid at the same time, the inverter(s) must sense that the other inverters powering the loads are NOT the "real" grid and that the "real" grid source is no longer available. The inverters must disconnect themselves from the "false" grid in less than two seconds if other inverters are attempting to maintain the grid by back-feeding. This is a requirement of the basic design of the inverter protection system laid down in AS4777 Part 3.

Vintage radio production photos were magnificent

My congratulations to Kevin Poulter for his Vintage Radio article in the June 2011 issue of Silicon Chip. This was a great story of bygone times, supported by a large array of magnificent photos.

As reported by Kevin, photos of radio production lines were rarely taken, let alone made available outside the factories. These outstanding photos are the results of Kevin's exceptional skills with things photographic and they should now live forever. Thanks for sharing them.

I wonder if we do still have any photos hidden away in this country of our own radio manufacturing factories? Probably sadly not but perhaps a comment which appeals to Silicon Chip readers who may have photos to share might prove my suspicions wrong. I certainly hope so.

Graeme Dennes
Bunyip, Vic.

Kevin Poulter comments: I have four excellent photos of Pye 2-way radio production in Clayton, Vic, circa 1960s and there are a few of AWA production in collectors' hands. The September 1964 issue of Radio, TV & Hobbies had a Pye UHF Tx/Rx being inspected in the factory.

The HRSA also has some photos of the EMI/HMV TV production lines in the mid-late 1960s. After extensive searches, I can advise that libraries around Australia including the National Archives have almost zero – just one or two of the Astor TV production and AWA TVs in about the 70s.

I would love to hear of anyone who has production photos.

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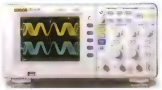

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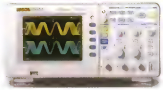

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Mailbag: continued

Persuading the retailers to market a kit

I was admiring the 12V 100W DC-DC Converter project (SILICON CHIP, May 2011) and considering the uses I could put it to. I started looking for who would be putting a kit out for it and have not found anyone as yet.

I was talking to some workmates and we all had the same complaint that we have to wait for someone to start marketing a kit and often a kit doesn't become available. Living in a regional area makes shopping for individual components a bit of a task.

What would be nice is somewhere we could register our interest in a project to show that there is a market for a kit. It would help the retailers who could take the risk knowing that there are X number of customers waiting. I build one kit a month and have done so for many years. I would be happy to build a few more.

I recently lobbied several retailers to produce a kit for the Solar Panel Simulator. I did not have any positive replies.

Chris Ryan,
Dubbo, NSW.

Comment: whether or not a kit is available is a decision for the kitset retailers, as you are aware. While we make the project information available to them before publication, it's up to them to decide whether to produce a kit for a particular project or not. We sometimes think they miss a golden opportunity to do some kits but maybe we are just biased.

If enough people ask for a kit, it might sway their decision. If a kit is not available, most if not all parts are available from Jaycar and Altronics on-line and the PCBs are also are available.

Typically, grid-connect inverters use both passive and active systems to check for the presence of the grid. Passive systems look for values of inverter voltage and frequency that are outside the preset grid limits.

If the grid fails, the free-running inverter quickly goes outside of the pre-set voltage and frequency limits. The passive anti-islanding system detects the erroneous conditions and initiates inverter shut-down.

Active systems attempt to gently push either the voltage or frequency (or both) of the grid away from the present value, which, of course, they cannot succeed in doing if the big alternators in the power station are sourcing the supply. However, if another inverter or a small "putt-putt" alternator is the source, that source WILL track the change and the inverter will find that it CAN cause the grid to vary – so the source can't be the grid! This will also trigger a shut-down.

Another active system involves the inverter determining the impedance of the grid from the V/I characteristics of the AC source, and if the source impedance is too high, the inverter will also shut down on anti-islanding protection. Excessively long, small cross-section AC inverter output cables can cause this system to give false alarm shut-downs with some inverters, as well as allowing shut-downs with genuine islanding situations.

The third problem is that all the settings for grid-connect systems be "secure" so the user or even a skilled technician can't get in and change them (AS4777 again). That means you'll have a lot of un-designing to do to overcome the anti-islanding systems if you want to run the inverter as a stand-alone unit – and then it will be illegal, irresponsible and downright dangerous to run it as a grid-connected system once the mains returns.

You will be much better off having a separate inverter system and either a second AC distribution system, or an approved AC change-over system to let you power your home from either the grid-connect inverter or the stand-alone inverter – but only from one at a time.

There ARE inverters that can grid-connect and run in both grid-available and grid-absent modes. These "special" units have an AC grid input/out-

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put, an AC load output and a DC system input/output. By comparison, a simple grid-connect system has an AC grid input/output and a DC input only.

If the grid is present, the "special" inverter will power the AC loads and back-feed any excess generation to the grid. If the grid is missing, the "special" inverters will disconnect themselves from the grid and use the inverters and DC sources to power only the loads. Most of these systems use batteries, as well as the solar array, to keep the loads running, even in low-light conditions.

If you use batteries to allow the inverter to operate under low-light conditions, you have created an Uninterruptible Power Supply (UPS) system. AS4777 says that a UPS installation needs separate switchboards for its AC loads, special battery storage areas, heavier DC cabling, fuses etc to cope with possible battery short-circuit currents (from the batteries right back to the solar panel protection), and a special ($$$) grid-connect inverter that will back-feed if the grid is there but won't back-feed if it isn't.

Brian Spencer,
Seaford, SA.

Comment: our investigation had centred on the concept of using a change-over contactor to isolate the home system from the grid and then tricking the grid-feed inverter into supplying power when the grid was down. When the grid came back, it would be up to the householder to switch the contactor back. But as your letter demonstrates in detail, this approach is simply not practical. Thanks for the information.

Noise-cancelling headphones on commercial flights

In these columns last year, I elicited advice on noise-cancelling headphones on commercial flights. None was forthcoming! Pity! With another Australian holiday looming in June 2011, I couldn't bear the thought of using the poor headphones issued by all major international airlines.

Recapping, readers may remember that I "borrowed" a pair of Singapore Airlines issue in 2010. These were of 300Ω impedance, with fully isolated left and right earpieces. Incidentally, I returned these to S.A. at Heathrow, much to their amusement.

We flew Qantas this time. I took a DMM with me and measured their headphones. Apart from the logo, they were identical to S.A. and I suspect to those in all other airlines. However, prior to departure, I bought a cheap pair of SilverCrest Model KH3447 stereo noise-cancelling headphones, 32Ω impedance, complete with long lead, two AAA batteries and an aircraft 2-pole adapter. These gave a huge improvement, especially as I'm slightly deaf in my left ear. Although I can't quantify the results, with noise-cancelling switched on, engine noise was considerably reduced.

Any disadvantages? Yes! The cheap but well-padded ear pads, sat "on" my ears. As I wear glasses, within an hour, my head felt as though crushed in a vise. Obviously, more expensive "around-the-ear" types are required but these are also usually bulky.

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Mailbag: continued

Technically, I pose the question again. Why are 300Ω headphone sets standard issue? If many more people used 32Ω sets or even 8Ω, would it overload the aircraft audio system? It begs some reader in the aircraft industry to do a technical article on aircraft entertainment systems. How about it?

Robert Gott,
Normanton, UK.

Technical standards are not mandatory

In the Mailbag pages of the May 2011 issue, Collyn Rivers raised a matter of standards and I would like to add my tuppence worth. I have spent a life as a Mechanical Engineer specialising in Fluid Power (hydraulics & pneumatics), to which the inclusion of electronics as a control element was a wonderful development. Throughout, I have been a strong advocate for standardisation.

Standards have been developed in many disciplines with benefits to manufacturers, end users and after markets. The adoption of standards is voluntary, not mandatory. As a member and later as chairman of Standards Australia, Committee ME35 – Fluid Power, over many years, I can attest to the difficulty in communicating these benefits.

So I have some sympathy with Collyn. What bugs me most is the use, by people who should know better, of the word meter to refer to a length. They never say which meters they use for the measure – was it a wattmeter or voltmeter used singly time and again or was it a string of ammeters, flow meters and pressure gauges side by side.

To Collyn I would say "Let it go mate and take consolation in the knowledge you would not have done it that way".

Kenneth W. Pilley,
Bonnells Bay, NSW.

Cassette recorders still wanted

I'd like to endorse B.P.'s comments on page 101 of the June 2011 issue of SILICON CHIP, about the need for a digital "tape" recorder. As an example, a friend of mine is a piano teacher who regularly used a cassette recorder as part of her program. She says that her old machine is beyond repair and that she can't find anything affordable that will do the same job.

Another acquaintance is a speech therapist who reports similar problems. Sangean recently came up with a portable digital radio (model DPR-17) with an SD-card socket for recording. It works very well but if they had included provision for a microphone as well I think this would have greatly increased the unit's versatility and appeal to purchasers.

Thus, may I strongly support B.P.'s request for you to produce a "high-quality recorder based on an SD card". I'm sure it would be of interest to both the technically and non-technically minded!

Stuart Hodgson,
Selby, Vic. SC

Details of Commodore 64 power supply

A recent letter to Ask SILICON CHIP concerned replacing the power supply unit for a Commodore 64 computer. The suggestion was that a 12V DC input might substitute for the 9V AC.

Unfortunately, this won't work. According to the schematic, the 9V AC input is used to generate a second +5V supply (via a conventional bridge rectifier/filter/linear regulator), used mainly by the audio and video output circuitry. This would still work with a DC input. However, the 9V AC also feeds a voltage doubler, via a series capacitor, to provide +12V from another regulator. This is used by the audio chip. A "+9V Unreg" supply is also generated, for the cassette motor.

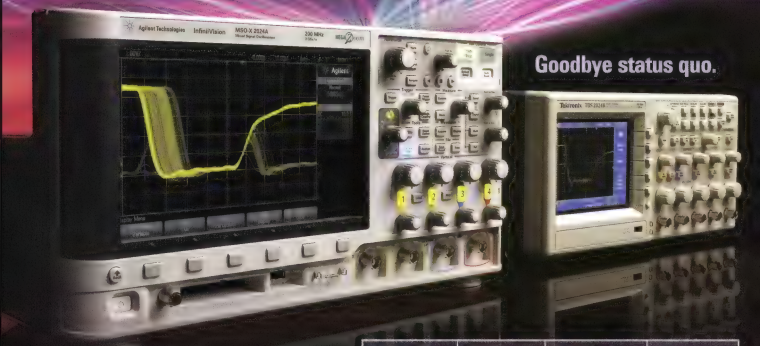
The 9V AC signal is also used to provide a 50Hz timing reference to the CIA chips. The 9V AC and 5V DC supplies should be derived from separate transformer windings, Jaycar MM-2014, or the MT-2082 toroid. One winding would provide the 9V AC, with a simple linear regulator circuit for the +5V DC.

I hope this information is useful.

Mike Phillips,
Adelaide, SA.

Read the review of the MSO-X 2024 4-channel oscilloscope in the Aprill 2011 issue of SILICON CHIP

Hello future.



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Max update rate (waveforms/sec)	50,000	200**	1,000,000	5,000
Fully upgradable	Yes	No	Yes	No
Function Generator	Yes	No	Yes	No
Notes:	**Refer to Agilent Pub 5989-7885EN for update rate measurements Data for competitive oscilloscopes from Tektronix publications 3GW-25645-0 and 3GW-22048-1 Measurements taken on same signal using Agilent MSOX2024A and Tektronix TDS2024B Screen images are actual screen captures and scopes are shown to scale			

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Australia Hears – and so do I!

Not too long ago we heard of an Australian company offering high performance digital hearing aids, based on new technology developed in Australia, at a fraction of the cost of other aids. I was intrigued – it's been a subject close to my ~~heart~~ ears for decades! Were they any good? Were they value for money? Did they work? And what is this latest technology in hearing aids, anyway? SILICON CHIP likes to look at electronics that are slightly out of the ordinary!

By Ross Tester

Regular readers will be aware of the series of hearing loop projects which we published during the latter part of last year and early this year to help the hearing impaired.

That prompted several requests for a build-it-yourself hearing aid. But as you would realise, miniaturisation of this magnitude is way beyond the skill level of most people!

Just to prove the point, we obtained a "dead" hearing aid, broke it open and photographed its innards. Apart from the near-impossibility of anyone constructing the ultra-miniature PCB, where are you going to get the appropriately-shaped "case", the tiny speaker, the ear tube? You get the point, I'm sure.

So no, this is not a build-it-yourself hearing aid. However, it is a "do-it-yourself" hearing aid – an apparent contradiction which we'll get to shortly.

But first, let's background this story a little. It's a sad, personal tale so keep the tissues handy.

For nearly four decades (since January 1973 in fact – I can still remember the day) I have had significant hearing loss in one ear.

It all started with a ***very*** loud – and painful – audio tone from a two-way radio earpiece in the laboratory at *Electronics Australia*. For a couple of months I heard nothing but ringing in my right ear. When that subsided and my hearing eventually "returned" in that ear I was very aware that my high-frequency hearing was virtually non-existent.

At my age then (early twenties) I should have been able to hear to at least 15-16kHz. I was flat out hearing 2kHz. Over the ensuing months, some higher frequencies were restored but it was virtually a brick wall at 4kHz – where it has largely remained to this day.

We broke open a modern hearing aid to show what's inside it. The "works" is on that tiny PCB (centre) while in this model, the miniature in-ear speaker is at the top of the picture.

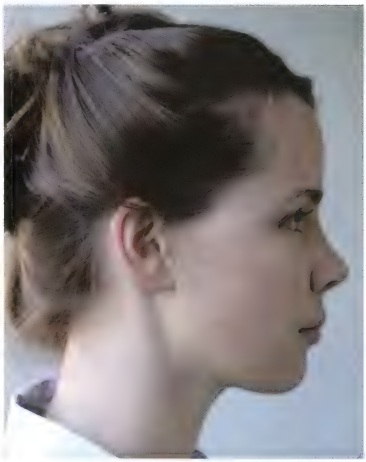
It's been something I (and, regrettably, everyone around me) have put up with ever since. And as I have aged, my "good" ear has also started to deteriorate, to the point where an audiologist described my hearing (especially in the right ear) as bordering on clinical deafness.

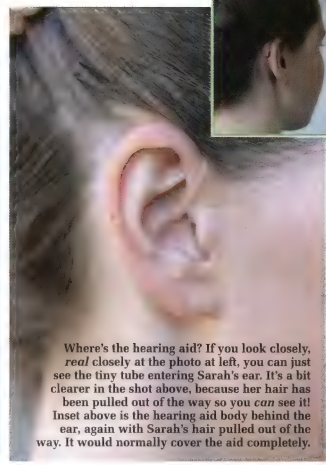
If you have never suffered from high frequency hearing loss, you could never understand just how difficult it is to decipher speech, in particular, with such a loss. Radio and TV programs particularly are terribly muffled (and turned up much too loud, according to everyone else!). Trying to understand conversations, particularly in a crowd or noisy environment, is almost impossible at times.

The closest thing I can think of to describe the problem is either an off-frequency AM radio station, without the sibilance or perhaps someone mumbling while speaking softly,

But apart from a couple of audiology tests done over the years (the most recent just on two years ago) I've done nothing about it. Why?

In the first of the hearing loop articles referred to above (October 2010),





Where's the hearing aid? If you look closely, *real* closely at the photo at left, you can just see the tiny tube entering Sarah's ear. It's a bit clearer in the shot above, because her hair has been pulled out of the way so you *can* see it! Inset above is the hearing aid body behind the ear, again with Sarah's hair pulled out of the way. It would normally cover the aid completely.

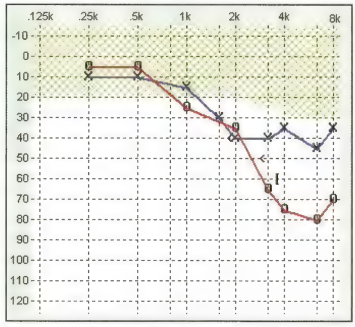
we said *"But there are many people in the community who have hearing loss and, for various reasons (cost, denial and vanity are the main ones!) don't own or want a hearing aid."*

I guess I fitted into the first and last categories. I certainly didn't deny I had a hearing problem but equally I didn't want a hearing aid – "they're only for old people . . ." etc etc. (Someone reminded me the other day that if I wasn't there already, I was rapidly approaching being a member of that august group!). But chief amongst my objections was that of cost.

At the time of the last audiology test, the specialist told me that I needed at least one, and preferably two, hearing aids – and then proceeded to show me models ranging from around $2,000 – "but you wouldn't want one of them, they're not real good" – right up to the latest and greatest wholly-in-ear models for only $12,000. Each!

I figured (alas incorrectly so far) that one day I would win Lotto, or perhaps stub my toe on a giant gold nugget while bushwalking and then I would buy myself some decent hearing aids. Or I would wait until I retired and get the pensioner's specials!

In the meantime, I'd persevere (or everyone else would!) with what was an annoyance but something I could live with, albeit often with difficulty.

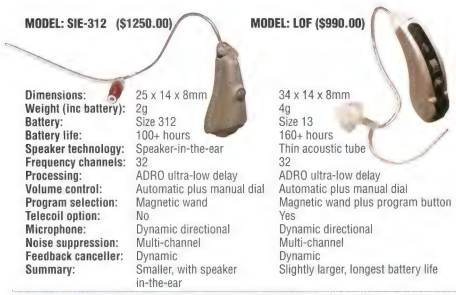


The computer-plotted audiology tests shows quite significant hearing loss below 2kHz in my right ear (red plot), the result of a very loud tone in that ear, in the *Electronics Australia* laboratory nearly 40 years ago.

Then it all changed

Late last April, several TV news programs carried a story on an Australian company who were introducing quality hearing aids at a fraction of the price of existing models. They were based on new technology called ADRO which, as far as I could understand from the news reports, was developed in conjunction with the people responsible for the cochlear ear transplant program.

Unfortunately we missed the press launch but I saw the story on TV, with some interest. And so did the Editor of this esteemed publication – and next day he asked me



Comparison of the two models of ADRO hearing aids from Australia Hears. There's not much between them – the SIE with in-ear speaker is slightly smaller and lighter but the LOF model offers longer battery life and an extended hearing range. The LOF also has a Telecoil – we believe a very useful feature. Otherwise they're very similar in performance and usage.

to investigate further to see if there was the makings of a feature article for SILICON CHIP readers.

Now we're not saying we think all SILICON CHIP readers are in the "need a hearing aid" category. But of course many are, or are heading that way (or know people who are).

Just as important, though, are the younger readers who might have parents who would benefit.

And let's not forget that a huge proportion of younger readers in particular are almost certain to have significant hearing loss from (a) live music [why do bands have to play their music so damned loud?] and (b) excessive volume levels from the ear buds associated with their iPods/MP3 players/CD players etc [why do they have to play music so damned loud!].

One recent report said that at least 21% of people between 48 and 59 showed serious hearing loss. The researchers measured hearing loss as the ability to hear certain tones, and also as the ability to recognise words at different sound levels and words spoken by male and female voices.

They found that 14.1% of the 3,285 study participants of all ages had some level of hearing loss.

Another study surveyed a sample of children aged 12 to 19 in 2005 and 2006 and found that 19.5% had some hearing loss. One expert said that listening to loud sounds through earbuds – the tiny electronic speakers that fit into ears, for use with personal music players – is probably the main reason that more adolescents are losing some of their hearing

Incidentally, if you even think you might have a hearing problem, there are any number of web sites where you can do a free rudimentary hearing check. It won't replace the audiologist test , but it could give you the impetus to go and have that fair-dinkum test if it tells you that something is not quite right. Just Google free hearing test or somesuch words.

Australia Hears

But back to the subject at hand. The company concerned was Australia Hears Pty Ltd, based in Melbourne and the snippets we saw on the news was courtesy of a PR company which must be said, did a pretty good job.

So much so that my first few phone calls to Australia Hears were met by a recorded message saying that they had been overwhelmed by the reaction to the publicity and they'd get back to me as soon as possible. The contact-via-the-website method also had a similar message.

However (with more prompting from he who must be obeyed!) I eventually managed to get in touch with the company and more importantly, spoke with Dr Daniel Taft, their Chief Technology Officer.

I explained who I was and the fact that I would like to "review" their hearing aids for SILICON CHIP. Daniel was most accommodating with information and agreed that they would like to co-operate.

First of all, Daniel asked if I had an audiogram which I could send him. I explained that the most recent one was two years ago and he said that would do, so I sent him a PDF which I had obtained from the audiologist.

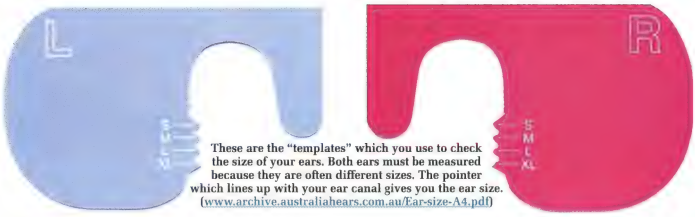
From this, he would "program" hearing aids to suit my particular hearing pattern. While this would tend to obviate any requirement for programming myself, we also got their "IHearYou" programmer package, which includes a USB programmer box, cables to connect the hearing aids and instructions – just so we could play.

They also wanted to know the size of my lug-holes because there are four different sizes to choose from. They have a cut-out template which you place over your ear and read off small, medium, large or extra large sizes.

Now just in case you think this was just a "freebie for Rosco" type of deal, I would point out that I paid full retail price for the products purchased from Australia Hears.

Program it yourself

Australia Hears' main claim to fame (or at least the message that we got from the news reports) was that they had developed digital hearing aids which were the latest technology but



These are the "templates" which you use to check the size of your ears. Both ears must be measured because they are often different sizes. The pointer which lines up with your ear canal gives you the ear size. (www.archive.australiahears.com.au/Ear-size-A4.pdf)

were about half the price (or even less) of comparable models on the market.

Coupled with that was the fact that you, as a user, can "tune" them to suit your particular circumstances. Hence the "do-it-yourself" comment earlier.

Of course, with the hearing aids pre-loaded with your audiogram, most people won't want or need to do that but it's comforting to know that, with the programmer box, you can. We'll look at the programmer in a bit more detail shortly.

Models

They offer two different models, the $1250.00 SIE-312 and the $990.00 LOF. The first thing you will notice, if you have been in the market for a hearing aid, is those prices.

SIE-312, the slightly smaller model, stands for speaker-in-the-ear and 312 is the battery size it takes. It has a very tiny "speaker", a tube about 2mm in diameter x 5mm long, at the end of ultra-thin wires.

LOF (which, incidentally, stands for liberty open fit), has its speaker within the body of the hearing aid connected to a thin (almost invisible) tube which feeds audio into the ear canal. Operationally, they are quite similar but the LOF battery life is longer (160 hours vs 100 hours) and its sound output is slightly greater.

Both have similar electronics, offering 32 digital frequency channels, adaptive automatic directional microphone, dynamic feedback cancellation and ultra-low delay.

According to Australia Hears, there is very little to choose from when selecting the model, apart from the price difference. If appearance is important, they suggest the SIE-312. It's the lighter of the two at just 2g and measures 25 x 14 x 8mm.

If longer battery life is your aim, then the slightly larger and heavier LOF is better. It's 34 x 14 x 8mm and weighs 4g. Having said that (and after wearing both) you don't notice the difference at all.

Characteristics of the hearing ranges are very slightly different at the low end (the LOF has a 10dB greater range at 250Hz) but this would not be of importance to the vast majority of users with high frequency hearing loss.

Both can have up to four programs stored in them (for different ranges, amplification, etc, to suit different environments, for example) and both have program switching via a small magnetic wand, packed with the hearing aid. The LOF also has a push-button switch on the body to achieve this.

Volume setting on both can be done via a tiny dial on the body but once set, you'll probably find you'll never touch it again as they have an automatic level control built in. The miniscule dynamic microphone is directional.

The only other major difference that I noticed, having an obvious interest in the subject, is that a Telecoil is an option on the LOF but is not available on the SIE-312.

So which one?

I didn't know which one to go for either, so at Australia Hears' suggestion, I purchased a pair of each to compare them for this feature.

I used them for a week at a time and, to be honest, I still cannot recommend one over the other! I will be returning one of the pairs shortly (within the 14 days satisfaction guarantee) for a full refund. But I can assure you I won't be returning both!

Wearing them

For someone who has never worn hearing aids before, I wondered whether they would be physically annoying. The first fifteen minutes convinced me there was nothing to worry about there.

First of all, though, you have to load the batteries. That's not difficult to do – the batteries only fit in one way and there's a card packed with the units to show how. Closing the battery doors immediately turn them on – there's no on/off switch as such.

Needless to say, there is a right and a left aid. This is not only for the physical reason of having the speaker/sound pipe emerging on the correct side to go into the ear but most importantly, the two hearing aids will very likely be programmed differently to take into account differences in the hearing loss.

It takes a bit of fiddling around the first time to find where they go and get the ear-canal part seated properly but once you've done it a couple of times, it becomes second nature.

After the first few minutes, it's very easy to forget that you a wearing a hearing aid (or two). They really are that comfortable to wear. Moreover, most people don't even notice you have them unless they get very up close and personal! I have quite short hair so if they were going to stand out they would do so on my head. But they don't.

And anyone with longer hair (especially females) would have them pretty-well completely hidden, as you can see from the two photos at the start of this article.

As I mentioned before the wires (SIE-312) or tube (LOF) which go into the ear canal are themselves so small they are almost invisible.

There's a range of small "ear tips" which slip over the end of the speaker or tube to hold it in the right place in the ear. Usage of the tips (and the type of tip) is optional – I found them to be very comfortable with and without.

The biggest problem I had was when one ear canal was itchy and had to

ADRO©: a new approach to amplification in hearing aids . . .

Professor Peter Blamey, the founder and managing director of Australia Hears, has spent the past 30 years researching ways to improve the sound quality of cochlear implants and hearing aids. Blamey is also deputy director of The Bionic Ear Institute.

He has long been aware of the limitations of conventional digital hearing aids designed to compress a wide range of input sounds into a narrower output range. In 1998, he hit upon the idea of using a processing chip within the aids to select the most informative parts of a sound range and present them at comfortable levels at each frequency for the listener.

The Adaptive Dynamic Range Optimisation (ADRO) technology he invented splits sound into 32 different frequency channels, then uses statistical rules as part of the digital amplification strategy to optimise the audibility, comfort and intelligibility of sounds without compromising sound quality.

The rules are set for each individual user and keep the audibility and comfort levels the same as those of a person with normal hearing. If the sound falls below the audibility target, it is made louder, while if it rises above the comfort target, it is made softer.

Each individual can set his or her own comfort levels for different environments with an easy-to-use software program. This eliminates the need to fit hearing aids on the basis of the averages of a sample population as done with conventional hearing aids — a boon for individuals whose hearing preferences are not typical.

Even the software used to customise the hearing aids is evidence-based, using data collected from 176 ears to predict and suggest amplification levels to the individual.

"Conventional compression technology can match ADRO technology in terms of audibility or comfort but not both simultaneously unless very high compression ratios are used. However, application of these high compression ratios can reduce speech intelligibility in background noise and adversely affect sound quality in quiet surroundings," Blamey notes.

Fuzzy logic makes sense

ADRO hearing aids work on four 'fuzzy logic' statistical rules, which can be true for part of the time rather than always being true or false.

Each rule has a critical role and is applied independently to each of the 32 frequency channels in an individual's hearing aids.

The **comfort rule** ensures that sustained sounds are not too loud more than 10% of the time.

The **audibility rule** ensures that sustained sounds are not too soft for more than 30% of the time.

The **hearing protection rule** stops sudden loud sounds from being amplified beyond a maximum level for the listener.

The **background noise rule** prevents low-level background noise from being over-amplified and annoying to the user.

The result is that soft sounds are more audible, loud sounds are more comfortable, intelligibility for speech in background noise is improved while preferred sound quality is provided.

Applying four standards

Hearing aids from Australia Hears include four standards that enable easier and more flexible customisation.

1. The ADRO processor optimises sound for a listener across 32 different frequency channels.

2. An automatic adaptive directional microphone reduces the loudness of background noise from some directions.

Research shows that these microphones provide better speech perception than either omnidirectional or fixed directional microphones.

3. Incorporation of adaptive feedback cancellation that prevents the high-pitched whistles of feedback loops that occur when the microphone of an amplifier is too close to its speaker.

4. Ultra-low delay processing technology to eliminate perceptible distortions or echoes caused by sound delays as sound is processed from analog to digital signals. The Australia Hears technology has the shortest delay of any device in the industry.

Professor Peter Blamey, inventor of ADRO and founder of "Australia Hears".

Clinical trials

The ADRO amplifier has been evaluated against an alternative amplifier in several clinical trials, which were conducted by the Cooperative Research Centre (CRC) for Cochlear Implant and Hearing Aid Innovation in Melbourne. 42 experienced hearing aid users preferred hearing aids with ADRO sound processors over conventional compression processors in most situations. Noted were improved sound quality, improved speech perception in quiet and in noise, and improved loudness control.

Additional uses

ADRO also has the flexibility required to improve hearing for any level of hearing loss, whether it's a person with normal hearing using headsets and telephones, a person with mild hearing loss who needs hearing aids, or a person with severe-to-profound hearing loss who requires a cochlear implant.

"ADRO is being applied in headsets and other devices for listeners with normal hearing to provide improved audibility and intelligibility to compensate for poor telephone transmission lines, and to protect hearing from loud sounds and acoustic trauma," Blamey explains.

In 2007, Blamey was honoured by the American Academy of Audiology with the International Award for his work in hearing and language research.

Product heritage

The products of Australia Hears are based on research conducted at the Bionic Ear Institute, funded by the CRC for Cochlear Implant and Hearing Aid Innovation. ADRO is copyright© Dynamic Hearing Pty Ltd and is the technology used in cochlear implant sound processors made by Cochlear Limited of Sydney.

The digital signal processing algorithms were developed at Dynamic Hearing in Melbourne and the House Ear Institute in Los Angeles and are licensed from Dynamic Hearing Pty Ltd.

The hearing aids are manufactured in Thailand using high-quality components including digital signal processing (DSP) chips from Sound Design Technologies in Burlington, Canada, and microphones and speakers from Knowles of Itasca, Illinois.

remove the aid to scratch it. But as any ear specialist will tell you, the smallest thing you should put in your ear is your elbow!

I am very much a beach/water person and I live in dread of the day I will forget to take them out before swimming, or even showering. They really are that comfortable!

If this happens, perish the thought, I take some comfort in the fact that Australia Hears offers a repair service – if they are damaged at all (I read a comment from one user who forgot to take them off before showering but simply dried them off and they continued to work perfectly).

How do they sound?

Obviously, I have no yardstick to judge them by (except years of poor hearing). I've only ever worn earphones or earbuds before. As an aside, I have to say earbuds annoy the life out of me! Give me a comfy set of conventional earphones anytime – and I am delighted to report that you can use headphones (not earbuds) with these hearing aids. While you can adjust the individual levels of most headphones, with hearing aids adjusted properly, you'll never have to do so.

My first reaction was, I have to say, shock. Not bad shock, just . . . shock!

Everyday tasks such as typing on a keyboard, running a tap, stirring a cup of tea, picking up a set of keys, even walking, had so much more "sound" to them than I had been experiencing.

In some cases, a jangly, jarring sound. In fact, for an hour or two, I found it quite unnerving. But as I got used to it, I started to realise it was simply what I had been missing all these years.

What I had been missing was obviously not only the high frequencies but the harmonics present in virtually every sound.

These harmonics go right up through the "normal" human audio passband of 15-20,000Hz.

Wearing glasses

That was one area I was worried about – I wear glasses virtually all the time and I thought that the glasses might interfere with the hearing aids, might rub on them creating a lot of unwanted noises or might prevent them being located properly.

None of these worries has proved to be warranted. Sure, if I move the glasses over the hearing aids (they normally sit on top of them) I can sometimes hear a sound but it's certainly nothing to be concerned about.

Some observations

My greatest hearing problem has been listening to people in a crowded room or with lots of background noise. That, I am happy to say, is very much alleviated. Even one-on-one speech is much easier to understand now – and I don't have to ask people to speak up (in fact, I've asked a few people to speak more softly!).

I also used to have trouble listening to soft radio (particularly voices) and TV sound – it was always muffled and half the time, I couldn't make out what was being said – female voices, especially, were a real problem. That too is now much better and as I get more used to the hearing aids, is getting better all the time.

I can hear sounds/noises I simply couldn't hear before. In fact, just about everything seems to be louder – while it is great most of the time, if I find it distracting, I simply remove the ear tube.

At long last, I can actually hear the buzzer in my multimeter! It's been a bane of my electronics life for years . . .

My partner has become used to talking very loud to me and also having the TV etc volume way up. Now I find that obtrusive! In fact, the first night I had the hearing aids in she asked me to turn the TV up because I had it too low!

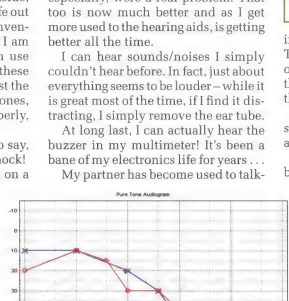
I've also discovered my car has squeaks and rattles I didn't know about. They're quite disconcerting!

I've found a loose floor tile in my bathroom – it has a squeak I had never heard before.

Traffic and wind noise while driving is more accentuated. I have a soft-top car so this is probably something I should have been hearing all along . . .

Feedback, once the bane of hearing aids, is almost – but not quite – eliminated. If you, or something, covers the area over the hearing aid (obviously creating a feedback path), you might get a quick "chirp". It's not all that loud, certainly not loud enough to cause discomfort, but it can occur. I notice it when I put on or take off the hearing aids sometimes; other times when my ear is too close to the car window.

Perhaps the worst thing, believe it or not, is the noise our dog makes! Tessie loves playing with empty PET drink bottles, attacking them, pushing them around a tiled floor, biting into them, banging them onto furniture and so on. But now, I find the noise a real problem. The barking also seems to be much more intense.



For comparison, here is the audiogram for my hearing with the LOF hearing aids fitted. The big dip at 6kHz is almost certainly the result of my reprogramming the aids to reduce the "jarring" sounds I mentioned. Otherwise the measured differences are quite subtle – most noticeable is the 5dB increase at 8kHz in the right ear (red trace).

What's a Telecoil?

We mentioned that the LOF model can be programmed to work with a Telecoil. But you may be wondering what the Telecoil is and why it is important.

Hearing aids with a Telecoil option can take advantage of (a) special telephones (intended for hearing impaired) that have a coil fitted which inductively couples the hearing aid to the phone, allowing clearer phone calls; and (b) halls, churches, offices and the like which are now increasingly being fitted with "hearing loops". Here audio signal (the same as normal-hearing people are hearing) is fed into a large wire loop which can also couple into a Telecoil-enabled hearing aid.

The series of "hearing impaired" projects run in SILICON CHIP between October 2010 and April 2011 were all Hearing Loop/Telecoil devices, including installing such a loop in your own home.

IHearYou programmer with its software and connecting leads. In all cases, the right hearing aid is coloured red and the left is coloured blue. The small adaptor leads almost underneath the programmer are the connectors to your hearing aids – we originally had them upside down and they didn't work!

I have since fiddled slightly with the hearing aid programming (see below) to try to reduce this harshness – it's something that I will continue to experiment with as I get more and more used to hearing aids.

IHearYou programmer

I mentioned earlier that if you supply your audiogram, Australia Hears will pre-program your hearing aids for you and the odds are that you will be completely happy with them.

However, we like to tinker, don't we. We like to see if we can improve on perfection.

Or we might want to set up a particular profile for a specific application (perhaps something to do with work, for example).

That's where the IHearYou programmer is used.

It's another $275 so it might be considered a bit extravagant for many users but . . . what the heck. We wanted to see what we could do with the hearing aid program.

It's a USB device and comes with software to make programming quite simple. All you do is load the software, plug the unit in and then connect it to your hearing aids.

Ahh – problem. It didn't work! So the usual solution applies – if all else fails, read the instructions.

The problem was that I had the tiny hearing aid connectors upside down. I had taken the instructions saying "shiny side up" to mean the shiny (plastic) side up. Somewhere else I found they actually meant the copper side up. Woops.

Those connectors are quite fiddly to get inserted properly but once I succeeded, the software told me that the AHPRO3 programmer was communicating with the hearing aids and then presented me with a range of options – all of which are quite intuitive.

I found the original program for the hearing aids was fairly close to ideal but I did take the opportunity to knock the treble back just a tad, to overcome that jangly noise thing I mentioned earlier. If I didn't have the programmer, I certainly wouldn't have worried about it and I may even reverse it later.

Incidentally, the other use for the programmer is to set up the parameters for Telecoil operation, which you simply load as one of the programs.

I also mentioned eariler that the program selection is achieved via a small magnet which is packaged with your hearing aids and/or, in the case of the LOF model, a tiny pushbutton switch.

LACE software

One thing I didn't order with my hearing aids – but may get in due course – is a specialised software program called "LACE". That stands for Listening and Communication Enhancement and is designed to retrain the brain to comprehend speech up to 40% better in difficult listening situations such as:

- noisy restaurants
- rapid speakers
- competing speakers

It is said to be especially valuable for anyone new to hearing aids but I also understand LACE to be valuable for anyone who might have problems understanding speech.

I downloaded a free demo version from the Australia Hears website and it looks to me, American voices notwithstanding, something that could really help comprehension. You can read several reviews and testimonials about LACE at the same source.

Priced at $99, it's available for Windows 7, XP and Vista, Apple OSX10.4 or newer computer systems and as well, is available on DVD for use on a home TV system.

OK, the verdict . . .

After wearing the hearing aids for little over a week, I'm sold. I have found my hearing rather significantly improved (as I would hope!) and apart from the itchy ear I mentioned before (which lasted only a day), have found them extremely comfortable to wear (indeed, I forget they are on most of the time).

It is obviously impossible for me to to an A:B:C comparison with any other hearing aids as far as clarity or overall audio is concerned but they'd have to go a long way to beat these from Australia Hears. And at the price paid, they're streets ahead. SC

Contact:

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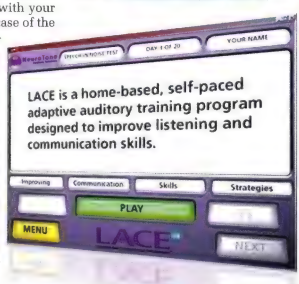
Website: www.australiahears.com.au



The evolution of electric cars:

Could there be a SIM-LEI in your future?

by Ross Tester

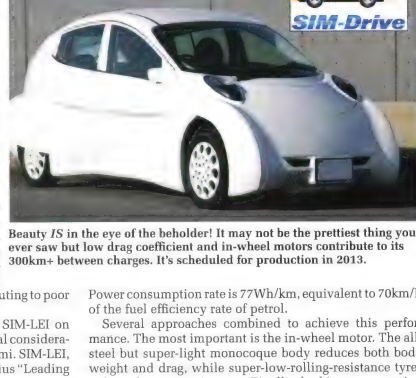
Correspondents in the May and June issues of SILICON CHIP made comment about the Mitsubishi i-MIEV (reviewed in the March issue) and electric vehicles in general. In the main, they were critical of the performance offered and in some cases, the design.

At least some of those criticisms may have been allayed with the announcement in late May of the "SIM-LEI" a new electric vehicle design from a Japanese consortium, Shimizu In-wheel Motor-Drive, or, as they abbreviate their name, SIM-Drive. Interestingly, the purpose of the company is not to manufacture electric vehicles themselves but to provide the highest level of electric vehicle technology and information, at the lowest cost, to all those involved with electric vehicles.

The SIM-LEI is not the first electric vehicle produced. In fact, they have developed 10 electric car prototypes over a 30-year period based on in-wheel motor drive technology. SIM-Drive believe they have overcome the traditional obstacles of enclosing the motor within the wheel, mainly an increase in unsprung weight, contributing to poor ride and increased wear and tear.

The consortium planned to announce the SIM-LEI on March 29 but this was delayed – not by technical considerations but by the Japanese earthquake and tsunami. SIM-LEI, by the way, comes from the consortium name plus "Leading Efficiency In-Wheel motor".

At the moment it's a concept car but it is scheduled to go into production in 2013. With the backing of some pretty heavy hitters in the consortium (including Mitsubishi and engineering firm IHI), one would be excused for believing that it just might happen.



Beauty *IS* in the eye of the beholder! It may not be the prettiest thing you ever saw but low drag coefficient and in-wheel motors contribute to its 300km+ between charges. It's scheduled for production in 2013.

Target range of 300km plus

The target performance of SIM-LEI was over 300km of range per charge, which is generally acknowledged as the major concern for the electrical vehicle market. The prototype exceeded this target, with 333km of range per charge under the "JC-08 mode" which represents general urban traffic condition in Japan.

The battery capacity to achieve this target is 24.5kWh, almost the same level as other electric vehicles presently in the market. The battery itself is lithium-ion. Power consumption rate is 77Wh/km, equivalent to 70km/L of the fuel efficiency rate of petrol.

Several approaches combined to achieve this performance. The most important is the in-wheel motor. The all-steel but super-light monocoque body reduces both body weight and drag, while super-low-rolling-resistance tyres reduce friction resistance. Finally, braking regeneration contributes significant energy savings.

The SIM-LEI is roughly the same length as a medium-size sedan and as wide as a compact car, with roomy leg space and a large boot space.

Performance

The acceleration performance, which is one of the outstanding features of the SIM-LEI, is 4.8 seconds for 0-100km/h (standing start). This is equivalent to, or even better than, many petrol-powered prestige sport cars.

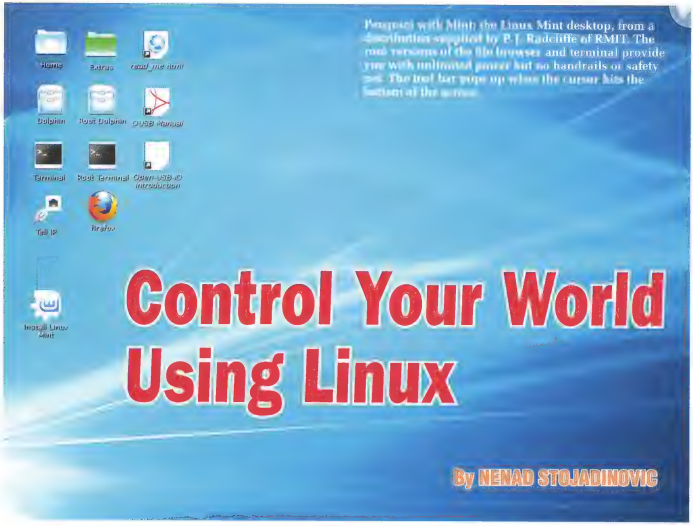
Developers were happy with both the long range and energy consumption of the SIM-LEI.

By using off-peak electricity, they believe vehicles such as the SIM-LEI could use excess generating capacity with no additional power generation plants needed but at the same time, significantly reduce a country's dependence on petroleum. SC

Specifications of SIM-LEI

Overall size (length/width/height):	4700mm/1600mm/1550mm
Number of seats:	4
Vehicle weight:	1650kg
Drive system	Outer rotor direct drive in-wheel motor
Drive:	4WD
Range per charge:*	(a) 333km (b) 305km
Driving energy consumption:*	(a) 77Wh/km (b) 84Wh/km
Standing start to 100km/h:	4.8 seconds
Maximum speed:	150km/h

** (a) JC-08 mode (b) at 100km/h constant*



Microcontrollers are becoming more powerful and sophisticated, to the point where they are challenging the supremacy of the PC. On the other hand, PCs running Linux are quite open and accessible to the experimenter. Yes, your computer can control your air-conditioning and lights and this article will show you how.

THIS ARTICLE is basically the first step (actually there are only two steps) to embedded computing using single-board computers (SBCs).

SBCs are generally just 5-8cm square and cram a complete PC onto a single circuit board. They are extensively used in applications requiring small size and/or resistance to vibration, such as automated teller machines, motor vehicles and portable machinery etc. These days, many run a version of Linux as the operating system due to its low cost, flexibility and range of development tools (some instead use one of the BSD-based Unix clones or Microsoft Windows).

They do tend to be rather basic, so it's much easier to do all development work in the luxury of your desktop PC, then stuff the finished software into the SBC when it's all debugged and running.

Technology directions

In the last year or two, SILICON CHIP has presented several spectacular examples of just what can be done with the newest generation of powerful microcontrollers. There has been the Web Server In A Box (WIB), the Data Logger and just recently, the Maximite computer. It gives an indication of the direction that technology has taken and it's amazing to think that a tiny piece of plastic and metal with a silicon "brain" can present you with seemingly endless pages of full-colour web content.

PCs have mirrored this upward trend but in so doing, have made themselves more and more inaccessible to the casual experimenter. It's harder to interface with USB than the older serial and parallel ports; even if you still have one of the latter, the latest Microsoft operating systems make writing software to access it a difficult task.

But then there's Linux. Linux is most certainly not such a black box.

In fact, everything is out in the open and it's really quite easy to access the various PC communication ports. By using Linux as the operating system (OS), you once again have a PC that you can experiment with. Want to log data, surf the web, flash LEDs or switch relays in response to varying light levels? No problem at all.

You may never have found much need to use to Linux and I certainly hadn't. But during the course of this work, I found that Linux is the number one choice for an embedded operating system, with "Android" (now commonly used in mobile phones) being perhaps the most famous derivative. This and many other embedded operating systems are based on the Linux kernel, which is the core component that provides all the basic functions.

The kernel is now up to version 2.6, and has a well-deserved reputation for functionality, stability and security.

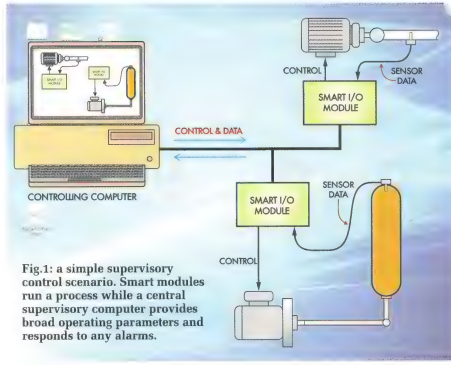


Fig.1: a simple supervisory control scenario. Smart modules run a process while a central supervisory computer provides broad operating parameters and responds to any alarms.

Linux control paths

There are three clear paths to Linux control and it's worth spending some time to explore them.

The first is the simple, old-fashioned use of the serial and parallel ports. Yes, I know that they have been largely phased out but rumours of their deaths have been greatly exaggerated. Suitable interface cards are readily and cheaply available (including USB-to-serial or USB-to-parallel adaptors) and the average desktop PC has lots of space to fit them. Likewise, many embedded applications still use them and a glance through the Ocean Controls catalog will quickly illustrate the point.

The second path involves the use of USB I/O (input/output) devices. They come in every imaginable configuration, from simple USB converter cables to boxes full of relays, ADCs and digital outputs – all driven from the USB port. For a (very) good example, take a look at the Arduino-compatible I/O controller featured in the April 2010 issue of Silicon Chip.

However, while the above approach is very useful, it has two failings: (1) the devices are generally "brainless"; and (2) it is difficult to use a PC in real time for such tasks. Your controlled system can be going haywire and overrunning its limit switches while the computer is blithely servicing some trivial interrupt.

A better approach is "supervisory control" (see Fig 1). It can be used with a bewildering variety of busses and protocols but let's assume for the moment that it's all USB. In that case, the PC and one or more USB I/O devices are linked together in a network, except now the USB I/Os are intelligent.

An an analogy, imagine a ship's captain and engine room crew. The captain (supervisory computer) drives the boat according to a plan involving high order functions such as navigation, sea state, schedule etc. The captain issues orders to the engine room for a certain speed and the engine room crew (USB I/O modules) takes care of monitoring and adjusting for steam pressure, engine operating parameters, lubrication and all the myriad functions that the captain does not want (or need) to worry about.

The point is that each control module can monitor and adjust for its own feedbacks in real-time so the PC can then interact with them on its own schedule.

The battle plan

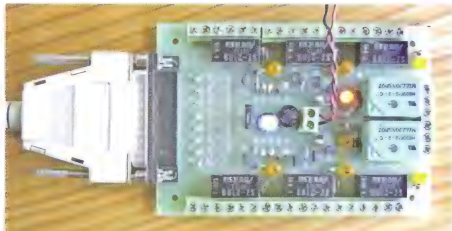
Let's start with a simple example of PC hardware control, a basic serial/parallel control system. While there are many more complex systems, this has the potential to occupy the ardent experimenter for some time.

As mentioned above, using Linux is essential to making this easy. The Linux interface is not hugely difficult to master but it has some important differences compared to Windows (and many similarities). An article in the March 2009 issue of Silicon Chip ("Reviving Old Laptops With Puppy Linux") covered the basics quite well and is recommended for the new chum (thanks Warrick).

In my case, I chose to purchase a Linux disk from P. J. Radcliffe of RMIT, who presented an intelligent USB I/O Interface in the October 2009 Silicon Chip. As part of the development, he produced a live DVD that is set up specifically for this sort of work and is furthermore stuffed with all sorts of tools and data (see **http://interestingbytes.wordpress.com/hello/open-usb-io-interface-board/**). Selling for a paltry $8.80, it is one of the world's few remaining bargains.

For this project, I obtained a PC built in 2005 with both parallel and serial ports and set it up near my usual computer so that I could hop onto the net at any time to check up on some arcane Linux command. It would also let me experiment without the fear of "killing" my good computer. The total cost of the set-up was just the price of the Linux DVD plus the computer, which still came to a total of $8.80, ie, the computer was scrounged for free (I did have to duck the hordes of people that also tried to "donate" their excess computers).

Now Linux is available in many



A relay board with a parallel port interface. These are available from many sources, eg, Ocean Controls. Setting an output bit high on the parallel port closes the corresponding relay.

different "flavours" (called distributions). These contain the same basic components (kernel, graphical user interface etc) but they are pre-configured in various different ways.

Just about any distribution will do for this task but I rather like Ubuntu. Also many distributions (Ubuntu included) provide a "live CD" or "live DVD" mode where the operating system is booted off the installation disk. The advantage of working this way is that if you make a mistake and cause it to lock up or you mess up some critical system file, you simply reboot and all will be pristine again. And if you use P. J. Radcliffe's DVD in this manner, you will find that the desktop and the directories are prearranged for ease of use in this mode.

Into the breach

The first step is to make sure you can boot from the DVD. Reboot your computer and watch for the message that tells you how to get into BIOS – generally you must press DEL, ESC or F1 early on in the boot process. Once in the BIOS menu, wade through the options until you find the setting for "Boot Order", then follow the on-screen directions to move the DVD-ROM to the first line (if it isn't there already).

Next, go to the peripherals set-up menu. There you will find several options for the parallel port and you will need to set it to "SPP" mode (or bi-directional or compatible, depending on the BIOS).

Having done that, put the Linux DVD in the drive, then save and exit the BIOS settings, which should reboot the computer. Booting from DVD is a bit slow but you will eventually be rewarded with the Linux Mint desktop (assuming that you are using the recommended distribution; see lead photo). Note the terminal and Dolphin icons – they will become your friends.

Booting the machine from a DVD means that you will have to store your working files elsewhere. If you have an old 1GB USB stick laying around, it will be more than sufficient. Plug it into your favourite computer and rename it something simple like "work" because you'll be typing it a lot (it's easier if there are no spaces in the name). Watch out – unlike Windows, Linux is also case sensitive, ie, "work" and "Work" are treated differently.

Next, download the files you will need from the SILICON CHIP website (see the panel for a list of files and sources) and save them to the USB drive. That done, plug the USB stick into the Linux machine and open up the Dolphin (or other) file browser.

Note that Linux does NOT identify disk drives with letters like Windows (C:, D: etc), though it does show you your disk as an icon for convenience. The topmost directory level is root, denoted by a single forward slash (/). Everything else is then under root as in **/bin** or **/usr** etc and you will find your drive mounted as **/media/work** (depending on what exact name you assigned to it). Rummage around and make sure it is there, as it's harder for beginners to do this when working in the terminal.

Things now terminal

For Windows users, it all gets much less familiar beyond this point (but if you're old enough to remember DOS, this will be nostalgic). Open up a root terminal using the desktop icon and enter the following commands:

user ~ # cd /media
user media # cd work
user work #

The hash (#) in the prompt shows that you are working as root, which means you have full access to the computer. Otherwise, you would see a $ (dollar) sign (a bit ironic given that Linux is free) and would have more limited access. You will need to learn the following commands:

ls -1 (list the files and do it neatly)
pwd (print working directory, ie, current location)
cd .. (go up one directory level)
./my_program (run *my_program* from this directory)

Note that you don't normally use the root terminal, as it does not have any safety constraints. Instead, it is more usual to prefix a command with **sudo**, which has the same effect but only for that command. Linux has various levels of permissions for reading and writing files and executing programs but the root (or "super user"/administrator) rules them all and can do anything and everything (including trashing important files!). That's why we're operating from a DVD. Also, some programs are not usable without root access, so it's easier in this case to simply use the root account.

The terminal will now have access to the directory that holds your USB drive. Type **ls -1** to see if your files are all present and accounted for.

The provided programs are all written in the "C" language, so they will need to be "compiled" into executable program files before they can be run. Linux generally has a C compiler ready to go and you can invoke it by typing "gcc" (which stands for Gnu Compiler Collection) at the command prompt:

user work # gcc -O -o lp_tty_start lp_tty_start.c

This compiles the C program **lp_tty_start.c** into an executable binary file called **lp_tty_start**. The "-O" flag tells the compiler to perform an optimisation pass, producing a faster program. This is not to be confused with "-o" which tells it that the output file name follows.

Sources For Information, Hardware & Software

(1). **http://linuxgazette.net/118/chang.html** (interface ADC with parallel port)

(2). **http://linuxgazette.net/112/radcliffe.html** (general introduction to interfacing serial and parallel ports)

(3). **www.interestingbytes.wordpress.com** (Linux Mint development system on DVD-ROM and intelligent USB IO)

(4). **www.oceancontrols.com.au** (network and control hardware, for industry and hobby users)

(5). **www.siliconchip.com.au** (download site for the software relating to this article in zip format)

Do the same for **port_write_then_read.c**, **port_read.c** and **tx_rx_serial.c**, remembering to change both the C source file and executable file names for each; ie,

```
user work # gcc -O -o port_write_then_read port_write_then_read.c
```

```
user work # gcc -O -o port_read port_read.c
```

```
user work # gcc -O -o tx_rx_serial tx_rx_serial.c
```

Finally, create an executable called **pp_serial_check**, which combines no less than three separate C source files. To compile it type:

```
user work # gcc -O -o pp_serial_check main.c pp_access.c serial_access.c
```

It is worth noting that the source code listings of these serial programs are useful items in themselves and are neatly commented to make them as easy as possible to understand and use.

Limited hair, proceed carefully

If, like me, you don't have much hair left, you can't afford much in the way of frustration and need to consider each step with care.

First, check the operation of the ports with a loopback test. To do this, connect serial and parallel cables to the PC and look closely at the free ends of these cables (or peer into the ports at the back of the computer if you're a masochist). You will see little numbers and you need to connect pin 14 to pin 15 on the parallel cable and pin 6 to pin 7 on a 9-pin serial cable (or pin 6 to pin 4 on a 25-pin serial cable).

In my case, I used a paper clip to short the relevant pins for the parallel port and I got my daughter to hold a screwdriver to short out the relevant serial pins.

Now type in the following (mind the spaces and underscores):

```
user work # ./pp_serial_check run
```

Note that the serial check part only checks for the presence of a functioning serial port. It does not test the data transfer (see below). If that's all successful, then try outputting a value via the parallel port:

```
user work # ./lp_tty_start ./port_write_then_read 888 85
```

That outputs a value of 85 (decimal) or 55 (hex) or 01010101 (binary) onto LPT1, which is located at port 888 (often written as 378 hexadecimal). You can then connect the ground lead of your multimeter to any of pins 18-25 (all ground) and measure the port's output. Pin 2 is the bottom bit (D0), which should be 1 and the remaining bits run through to pin 9 (D7). The voltages should alternate as you scan the pins.

For this type of programming, it helps to become familiar with converting between decimal (base 10), hexadecimal (base 16) and binary (base two) numbers. Sending the number 1 (decimal) to the port will result in 00000001 (binary) going to the output pins (D0 high). Sending 128 (decimal) gives 1000000 (binary), ie, D7 high. If your calculator can't handle the maths, there are lots of web sites that will do the job.

You can read the state of the port pins by invoking **./port_read**; eg:

```
user work # ./lp_tty_start ./port_read 889
```

This will read the input of LPT1. Why 889? Parallel ports were originally designed for printers and the input port is at a different address to the output port. There are only five

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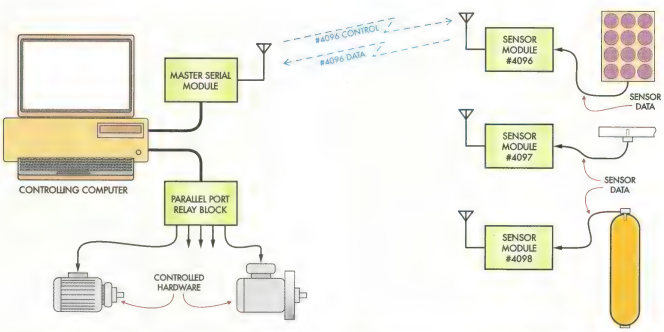

Fig:2: a more advanced control system. In this case, a radio serial transceiver module (eg, from Ocean Controls or Parallax) sends commands to remote stations which return data to be processed by the PC. A parallel port relay interface then switches pumps, valves etc.

input bits for a parallel port, located at pin 15 (D3), pin 13 (D4), pin 12 (D5), pin 10 (D6) and pin 11 (D7). Yes they are scrambled and the data for bit D7 is inverted!

There were plans afoot to make port 888 bidirectional but my computer certainly doesn't have that option. It's worth a try, though – just read port 888 while using a resistor to pull the pins high or low.

Serial comes to us

Serial data is much harder to deal with at first, because the data goes past in a blink and so you must capture it to debug it.

The solution is to use another computer to send and receive test messages. I scrounged an old laptop that runs Windows 3.1 (guess how much it cost!), with the Hyperterminal program for serial port I/O. I also splashed out and bought a null-modem interface cable (which connects one serial port's transmit pin to the other port's receive pin, and vice versa) from Jaycar for about $12 (Cat. WC 7513).

Serial ports are composite in that the serial data goes in and out of pins 2 & 3 while the rest of the pins are for handshaking signals and so are in fact quite like a little parallel port! However, it's complicated by the fact that the application must decide which is the master and which is the slave; the master cues up data and signals when it is ready to transmit, while the slave is generally sending data and must signal when it's ready to receive.

This can make life a bit complicated, especially when sending from peer to peer, but it's usually possible to simply ignore the physical handshaking functions and arrange for control signals to be embedded in the data if it becomes really necessary.

Linux serial ports are prefixed with "tty", which is from its early days as Unix, where the ports were used to drive teletypes. What is referred to as **COM1** in Windows is **ttyS0** in Linux (S is for serial). For USB, it is **ttyUSB**. Linux also differs in that the serial ports are accessible as files, eg, the first port is **/dev/ttyS0**.

There is a huge variety of serial software available for Linux, most from amateur programmers who needed a particular function or had a good idea that they pursued. I found that **GTKterm** (an improved version of Hyperterminal) is very useful for testing, as it will display any data that passes by. It is included in many Linux distributions (or "distros") and Mint makes it available from the toolbar which is at the bottom of the screen (under "Utilities").

Fig.2 shows a sample system that I built, with a number of microcontroller modules sending serial data to my control program which then switches pumps, heaters or valves as appropriate. I used radio modules for the serial link, because the remote sensors were in awkward positions.

For the serial communications, I started by running the program **tx_rx_serial** with port pins 2 & 3 linked together so that the data sent was immediately looped around to the data input. Once I knew that the port was running correctly, I simplified the program and set it up to send the appropriate commands to each sensor. This version is called **serialstim.c** and it will need to be compiled in the usual way. Run the compiled program and immediately the number 4096 should appear on the screen (why 4096? In binary it is 100000000000).

To test this, I then connected the laptop via the null modem cable and fired up Hyperterminal. With the appropriate port speed selected, I made up a text file with a number in it (actually it was the number 11) and cued it up with "send a file". It was then a simple matter of starting **serialstim** at the same time as I pressed the <enter> key on the laptop. Success was getting the number 4096 to appear on the laptop and the number 11 on the Linux machine.

LISTING 1: BASIC SCRIPT FILE (PASSWORDNDATA)

```
#!/bin/bash
set_val=11                          #Preset value
return=$( ./serialstim )            #Send command, get data in response
echo $return                        #Print received data to screen
if [ $return -ge $set_val ]         # Is reading above preset value?
  then  (./lp_tty_start ./port_write_then_read 888 1)    #Yes it is, set D0
  else (./lp_tty_start ./port_write_then_read 888 128)  #No it's not, set D7
fi
```

This basic script file (passwordndata.sh) sends a command to a remote terminal, receives data in return and switches a relay if a condition is met.

The command went one way and data came back the other. Cool.

Close the loop with a script

Passing data back and forth is all very well but nobody wants to sit around and operate stuff manually. How about controlling those pumps and valves? To achieve that, I tied it all together with script files.

When you type commands into the terminal, they are actually interpreted by a program called BASH (which stands for Bourne Again SHell). BASH is basically the command line interface between you and Linux and it was the only way of doing things in this operating system before its graphical user interfaces were developed.

Some clever person(s) realised that to save effort, it would be useful to be able to run common sets of commands without having to type them in every time. This is achieved using files called "shell scripts" which are a bit like DOS/Windows batch (*.BAT) or command (*.CMD) files. Additional commands were added to BASH to allow these scripts to be smarter; commands like "if", "while", "do" etc. Suddenly the command line had a form of programming called "BASH shell programming", based on script files.

With a shell script, you can do most of the things you expect from any program, with the added advantage of being able to easily utilise other programs, written in other languages such as "C" or Python (as well as other shell scripts). Furthermore, you can "pipe" the output from one program (say, your serial reception program) to the input of another program, perhaps a data analysis and control program.

Simple script file

The subject of BASH programming is much too large for an article such as this. The Linux community has obviously spent a lot of time developing the software and there are boundless references on the internet, though it can take a bit of hunting to find stuff that's written by a native of Earth.

However, to demonstrate, I've written a short script that uses all of the aspects covered so far – see Listing 1.

It does not need to be compiled and it is run by typing:

user work # sh ./passwordndata.sh

The script calls **serialstim** to send a command and then receives data transmitted from the remote sensor, which is then echoed (printed) to the screen. It compares the returned data to a set value. If it is equal to or above this value (*ge* = *G*reater than or *E*qual to), it activates the parallel port enabling program and the control program to send binary 00000001 to the port, thus activating the relay connected to D0. Conversely, if it's below the set value, it sends 1000000 to activate the relay on D7 and make sure that D0 is switched off.

It's a simple script and it demonstrates what can be done by unskilled labour. Remember though that you are only pottering around in one corner of a powerful computer. This simple script could easily be extended to, say, write the data to a file with a time stamp and then FTP the files to an address of your choosing. Then it would be easy to install web server software like Xampp so that you can access the system from all over the world (remote control is also possible using a program called **ssh** or Secure SHell).

In short, the applications are limitless, the software and support is all out there, and the price is right! SC

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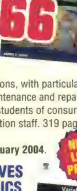

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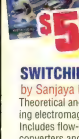

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Ultra-LD Mk.3 200W Amplifier Module

Upgraded design has even lower distortion!

The Ultra-LD Mk.2 (August-September 2008) was the lowest distortion class-AB amplifier board design ever published. But we have not rested on our laurels and have found ways to improve it significantly. The Mk.3 version has less than half as much distortion at frequencies of 2kHz and above. It also boasts much improved thermal stability, is slightly quieter and has a flatter frequency response.

By NICHOLAS VINEN

THE NEW AND UPDATED Ultra-LD Mk.3 is by far the best class-AB amplifier module design published anywhere. It has an astonishingly low total harmonic distortion plus noise (THD+N) figure of 0.004% at 20kHz for 100W into 8Ω (20Hz-80kHz measurement bandwidth) and less than 0.0006% THD+N at 1kHz and below.

The signal-to-noise ratio has also been slightly improved on the previous version (by 1dB) to -123dB with respect to 135W into an 8Ω load. The power output figures are unchanged with regards to the Mk.2 module.

All power measurements were made with a mains voltage of 230VAC, which is now common in Australia (although by no means universal). In locations with a higher mains voltage, slightly more output power is available. For example, if your mains voltage is normally 240VAC, you can expect about 8% more power output, eg, 145W into 8Ω.

The quiescent current accuracy, stability and thermal compensation have been dramatically improved compared to the Mk.2 and in fact are superior to any class-AB amplifier that we have tested. The new module has a trimpot so that the quiescent current can be set to the optimum (the Mk.2 was a bit hit and miss in this regard).

The new thermal compensation arrangement keeps the quiescent current well under control, even during and after sudden changes in dissipation. This contributes to the low distortion as it means that the output stage is always correctly biased.

Specifications & Performance

Output Power (230VAC mains)	200 watts RMS into 4Ω; 135 watts RMS into 8Ω
Frequency response	+0, -0.3dB (8Ω); +0, -1.0dB (4Ω) – 10Hz-20kHz (see Fig.5)
Input sensitivity	1.26V RMS for 135W into 8Ω; 1.08V RMS for 200W into 4Ω
Input Impedance	12kΩ
Rated Harmonic Distortion (8Ω)	<0.004% 20Hz-20kHz, typically 0.0006% (see Figs.1 & 3)
Rated Harmonic Distortion (4Ω)	<0.007% 20Hz-20kHz, typically 0.0006% (see Figs.2 & 4)
Signal-to-Noise Ratio	123dB unweighted with respect to 135W into 8Ω (22Hz to 22kHz)
Damping Factor	~180 with respect to 8Ω at 1kHz & below
Stability	unconditionally stable with any nominal speaker load ≥ 4Ω

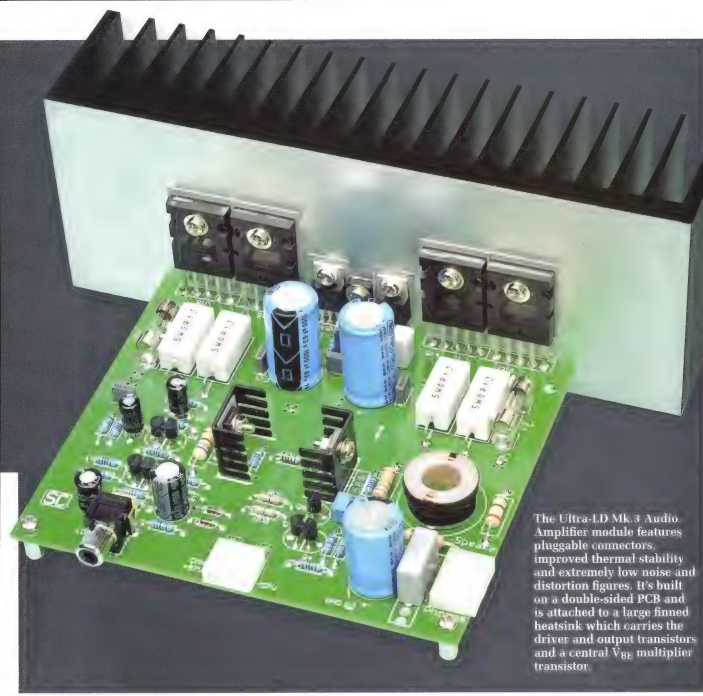
Rationale

Making these improvements to an amplifier that already had outstanding performance may seem like gilding the lily. But there are two important reasons why we decided to improve on the Ultra-LD Mk.2.

First, we felt that we could produce a design that was even closer to that holy grail of amplifier design: a high-power class-AB module with the low distortion of a Class-A amplifier. In fact, the new design is tantalisingly close to the benchmark SILICON CHIP Class-A amplifier (May-Sept. 2007).

Astute readers may have noticed that while the Ultra-LD Mk.2 was clearly superior to the original Ultra-LD amplifier (SILICON CHIP, March & May 2000), it actually had higher distortion for frequencies above 6kHz.

This is because the original Ultra-



The Ultra-LD Mk.3 Audio Amplifier module features pluggable connectors, improved thermal stability and extremely low noise and distortion figures. It's built on a double-sided PCB and is attached to a large finned heatsink which carries the driver and output transistors and a central V_{BE} multiplier transistor.

LD featured a more linear output stage, consisting of two complementary compound transistor pairs. By contrast, the Ultra-LD Mk.2 used a standard complementary Darlington emitter-follower output stage, for better current sharing between the output transistors (allowing it to reliably drive 4Ω loads).

Since then, we have tweaked the emitter-follower output stage to improve its linearity at high frequencies (more on this later). The end result is that the Mk.3 has distortion lower than or equal to both the original Ultra-LD and the Ultra-LD Mk.2 at all frequencies.

It may seem that the distortion products of very high frequencies (10kHz & above) are irrelevant, since they will all be above the audible range. The second harmonic of a 10kHz signal is 20kHz and the third is 30kHz and these are not audible so why are we trying to minimise their level?

The answer is intermodulation. While lower order harmonic distortion may be relatively benign, the associated and inevitable intermodulation distortion is definitely not benign; it is audibly unpleasant.

To demonstrate, let's say we have an audio signal consisting of a 10kHz sinewave mixed with an 11kHz sinewave. Their second harmonics are at 20kHz and 22kHz respectively and are not audible, but the difference products of 1kHz, 2kHz & 12kHz certainly are audible and are musically unrelated.

So by minimising harmonic distortion at high frequencies, we are also minimising intermodulation – a far more unpleasant distortion product.

Quiescent current

Second, we just weren't satisfied with the quiescent current and thermal compensation arrangement of the Ultra-LD Mk.2. That was our first design using the On Semiconductor

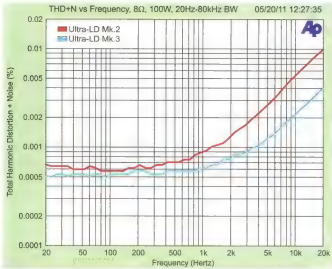


Fig.1: total harmonic distortion plus noise across the audible frequency range for an 8Ω load driven at 100W. This is an "apples-to-apples" comparison between the old and new amplifier modules with an identical power supply and test set-up. The Mk.3 is superior at all frequencies but especially above 1kHz.

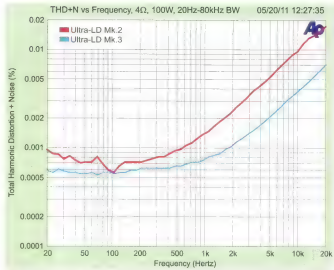


Fig.2: the total harmonic distortion plus noise across the audible frequency range for a 4Ω load driven at 100W. The performance improvement for the Mk.3 module is even larger with a 4Ω load, with less than half the distortion of the Mk.2 version across a large portion of the audio frequency range.

"ThermalTrak" transistors, which have integral diodes. The literature for these devices claims that they eliminate the need for quiescent current adjustment as well as providing much better thermal tracking than a traditional V_{BE} multiplier circuit.

Our initial prototypes seemed to confirm both points. But as more people built modules based on that design, it became apparent that the ThermalTrak transistors vary somewhat from batch to batch and therefore we do in fact need a method to trim the quiescent current.

Also, for reasons we shall explain later, many of the Ultra-LD Mk.2 modules built do not have good thermal tracking. That is to say, their quiescent current can vary considerably depending on the output device temperature, which can vary rapidly depending on the program material being played.

Once we found out about these problems we took a closer look at the ThermalTrak transistor data sheets. It turns out that the ThermalTrak diode temperature coefficient doesn't necessarily match that of the accompanying transistor and so using the diodes alone for thermal compensation is not satisfactory.

In some cases, the diode temperature coefficient is so much lower than the transistors' that the result can be thermal runaway – as the transistors get hotter, the quiescent current increases, making them hotter again until eventually they blow; definitely not a good state of affairs!

Back to the drawing board

Actually, building a class-AB amplifier with accurate thermal compensation that responds quickly to changes in dissipation is a very difficult task. The basic problem is that to get good performance, the standing current through the push-pull output transistors must be kept within a relatively small range (in this case, about 70-140mA per pair).

If the quiescent current is too low, the result is significant crossover distortion. As the output voltage passes through zero, the load current is "handed over" from one of the output transistors to the other. Without sufficient bias, one transistor turns off faster than the other turns on, resulting in a discontinuity in the output stage transconductance (ie, the ratio of its input voltage to output current).

This makes the amplifier as a whole less linear and so increases its distortion.

The opposite problem occurs if the quiescent current is too high. In this case there is actually a sudden increase in the transconductance in a voltage band around 0V. This is called "transconductance doubling" and again reduces linearity.

When the quiescent current is in the correct range, these two effects tend to balance out and so the transconductance curve for the output stage is as flat as possible, maximising linearity and thus minimising distortion. So we want to set it within that range and keep it there.

High quiescent current also causes excessive dissipation in the output devices – we don't have to explain why that's undesirable.

Thermal tracking

If the transistors were all kept at a constant temperature, correct biasing could easily be arranged by simply placing an adjustable floating voltage source between the base of the two driver transistors and then trimming it with an eye on the current through the output stage. This bias voltage sets the V_{BE} across the driver and output transistors, resulting in a constant standing current through the output stage.

Unfortunately, the required V_{BE} for constant current through a transistor depends on its junction temperature. Since the output transistors heat up and cool down during use in an unpredictable way (depending on the program material, load impedance, ambient temperature, airflow, etc), we must come up with a way for the bias voltage to vary with driver and output transistor temperature, to keep the quiescent current as stable as possible.

In the Mk.2 amplifier, the bias was developed by passing a constant current through the four ThermalTrak diodes contained within the output

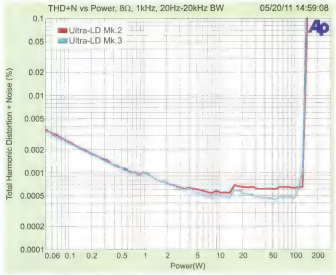


Fig.3: total harmonic distortion plus noise against power level for 1kHz into 8Ω. The slightly lower noise figure makes the Mk.3 marginally superior at low powers, with it pulling further ahead above 4W due to its lower harmonic distortion. Note that the maximum power available has hardly changed from the earlier design; the small variation is mainly due to the test procedure.

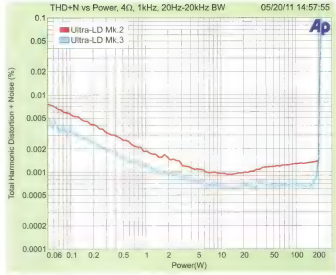


Fig.4: total harmonic distortion plus noise versus power for 1kHz into 4Ω at a range of power levels. Here the Mk.3 module really shines, providing significantly lower distortion across the entire range. The Mk.3 can easily produce the rated power of 200W into 4Ω. Note that the measurement bandwidth (20Hz-20kHz) is smaller than in Figs.1 & 2, so the figures are better.

transistor packages. As the output transistors heated up, the required V_{BE} for a given current dropped and so did the forward voltage of the associated diodes. If the two thermal coefficients matched, then theoretically the diodes would correctly compensate for the changing transistor properties with temperature.

Since that clearly wasn't happening, we decided to ignore what the application literature said about these transistors and instead analyse the circuit from first principles. We are not the only people to notice this problem. Douglas Self experienced similar difficulties using this type of transistor, which he documents in his *Audio Power Amplifier Design Handbook* (Fifth Edition).

In that book, he points out that if the ThermalTrak transistor data sheet is correct, the diode forward voltage temperature coefficient is -1.7mV/°C but the transistor V_{BE} temperature coefficient is -2.14mV/°C. Clearly then, we cannot use a single ThermalTrak diode to compensate for a single ThermalTrak transistor without risking thermal runaway (or at least a wildly varying quiescent current).

But that wasn't the only problem. The four ThermalTrak diodes compensated for four transistor V_{BE} drops but only two of those drops are from the base-emitter junctions of the power transistors that the diodes thermally track. The other two are the driver transistors (Q10 and Q11, MJE15030/MJE15031). So even if the diode thermal coefficients matched those of the output transistors, they wouldn't necessarily correctly compensate the driver transistors.

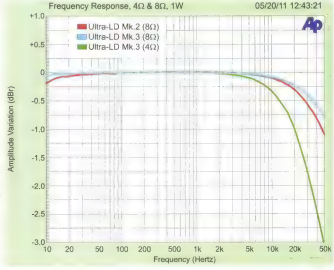
Also, there is significant thermal lag between the output transistors and the driver transistors, since during periods of high output power, the power transistors can get significantly hotter than the heatsink. It takes a while for the heatsink temperature to heat up in response to the increased dissipation and then there is a further thermal lag from the heatsink back to the driver transistors.

We had to find a better solution. As a result, we came up with several ideas for circuits that would provide a bias voltage with more accurate and reliable thermal tracking, then ran them through circuit simulations before building a prototype incorporating the most promising.

New design

Our new solution harks back to that tried and true bias compensation scheme, the good old V_{BE} multiplier. But we have also incorporated the ThermalTrak diodes as they are critical in allowing us to provide compensation for rapidly varying output device temperature.

Fig.5: the frequency response for the Ultra-LD Mk.3 module. Note that there is less roll-off at both the low-frequency and high-frequency ends for the Mk.3 compared to the Mk.2. The high-frequency roll-off is greater for 4Ω loads (about -1dB at 20kHz). This can be slightly improved (to -0.7dB) by changing the inductor – see Pt.2 next month.



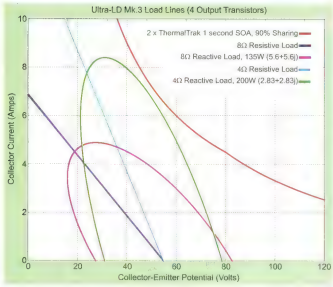


Fig.6: load lines for the Ultra-LD Mk.3 amplifier. The red line is the 1-second Safe Operating Area (SOA), outside of which transistor second breakdown becomes likely. The mauve and green lines represent realistic speaker operating areas for 8Ω and 4Ω units respectively, taking into account their reactance.

We are now using two ThermalTrak diodes to compensate for the two power transistor V_{BE} drops, in series with a V_{BE} multiplier to compensate for the driver transistor V_{BE} drops. The V_{BE} multiplier transistor is mounted on the heatsink, between the driver transistors, to best track their temperature.

Now that we have a V_{BE} multiplier, this allows us to easily provide an adjustment by placing a trimpot in the multiplier network. This means that the quiescent current can be configured correctly regardless of variations in the output transistors.

The adjustment will however slightly degrade the thermal tracking, since in changing the absolute voltage contribution of the V_{BE} multiplier (by changing the multiplication factor) we also change its thermal coefficient. But our testing shows that this is a relatively minor factor and the tracking is still more than good enough.

Actually, because the temperature coefficient of the ThermalTrak diodes is lower than that of the associated transistors, in order to achieve correct compensation, the V_{BE} multiplier must slightly over-compensate for changes in temperature. We found that if we used a BD139 for the V_{BE} multiplier, we achieved the required over-compensation. Simulation shows that the resulting quiescent current variation with temperature is virtually flat.

The prototype Ultra-LD Mk.3 modules were built from two different batches of ThermalTrak transistors and they bear this out. As a happy coincidence, it turns out that the best current to use for the new bias generating arrangement is the current that we originally chose for the Ultra-LD Mk.2 (9.5mA) to provide the best performance.

Parallel diodes

While we stated earlier that we are only using two of the ThermalTrak diodes, we have actually wired up all four on the PCB, in two parallel pairs which are then connected in series. This makes it possible to build the amplifier with only two output transistors (the outer pair), for applications where less power is required. The supply voltage is also reduced in this case, to reduce overall power dissipation.

Lower distortion

As stated, the Ultra-LD Mk.3 has less than half the distortion of the Mk.2 at frequencies of 2kHz and above (see Figs.1-4). It also has lower distortion at low frequencies but there is so little to measure that it tends to be lost in the noise floor (not that there is much of that either).

There are two main changes which reduce the distortion and these are the new frequency compensation arrangement and the new driver transistor emitter resistor configuration (ie, for Q10 & Q11). Of these, the latter is the most important but they both contribute to the excellent performance.

With the Ultra-LD Mk.2, the driver emitters were connected to the output via 100Ω resistors. For the new circuit, the emitters are instead connected to each other via a 220Ω resistor which is bypassed with a 470nF capacitor.

This allows the driver transistors to reverse-bias one pair of the output transistors to switch them off quickly, when the slew rate is high (ie, at high frequencies). This was not possible with the old arrangement. Reverse-biasing the output transistor base-emitter junction rapidly removes the charge carriers from it, preventing conduction which would otherwise occur for some period after the normal base drive was removed.

The 470nF bypass capacitor assists in the switch-off process. The bottom line is lower distortion at high frequencies.

Two-pole compensation

The new compensation scheme also helps to lower the distortion. Instead of a single 100pF, 100V ceramic capacitor between the base of Q8 and the collector of Q9, we now have two 180pF 100V polypropylene (plastic dielectric) capacitors and a 2.2kΩ resistor. This dramatically increases the open-loop gain within the 20Hz-20kHz frequency range without affecting stability.

For more details on why and how this works, see the separate feature article titled "Amplifier Stability and Compensation" in this issue.

We found that polypropylene capacitors gave measurably less distortion compared to C0G/NP0 ceramic capacitors of the same value, presumably due to their higher linearity. Ceramic capacitors can be used but the distortion at 20kHz will increase from around 0.0048% to about 0.0055% (with proportionally similar increases at lower frequencies, down to about 1kHz).

Feedback network changes

During the course of testing the prototypes, we ran into a problem with the capacitor in the feedback network (above and to the left of Q8). The purpose of this capacitor is to reduce the amplifier's DC offset at the output, by reducing the DC gain to one.

The original capacitor was specified as 220µF but we found that if the capacitor value was on the low side and/or the capacitor used had particularly bad non-linearity (as is sometimes the case), the result could be a significant rise in distortion below 50Hz. By changing this capacitor to 1000µF, we eliminated that possibility. This also improves the signal-to-noise

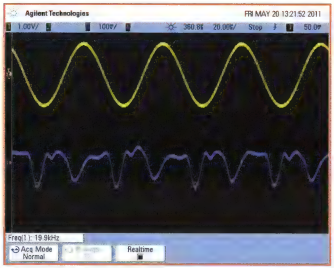


Fig.7: an oscilloscope screen grab illustrating the shape of the distortion residual waveform for a 20kHz sinewave at 100W into 8Ω. It is primarily second harmonic, with some third harmonic (how much depends on how well-matched the output transistors are in terms of beta). We have to demonstrate the distortion at a high frequency and power level otherwise it's hard to see!

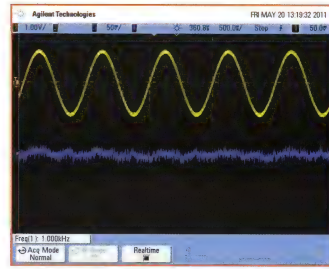


Fig.8: by contrast with Fig.7, this scope grab shows the extremely low distortion when delivering 100W into 8Ω at 1kHz. Note that the distortion is virtually buried in the noise (blue trace). Averaging the distortion product signal shows it to be mainly second harmonic at a very low level. This low-level harmonic distortion is virtually the same whether at 50mW or 100W.

ratio, by about 1dB, because it lowers the source impedance seen by the inverting input (the base of transistor Q2) at low frequencies. In addition, it flattens the low frequency response, as can be seen in Fig.5.

Input filter changes

We have increased the value of the RF filter capacitor at the input, from 820pF to 4.7nF. This allows it to better reject supersonic components of the input signal (eg, digital-to-analog converter switching artefacts). This value suits signals sources with low output impedance (0-220Ω). Virtually all CD/DVD/SACD/BluRay players, preamplifiers, computer sound cards and DACs should be within this range.

If a volume control potentiometer is to be installed immediately before the power amplifier, with no buffering between the two, or if the signal source(s) will have an output impedance above 220Ω, reduce this capacitor value to 1nF. Otherwise, the high frequency response of the amplifier will suffer.

PCB improvements

As well as updating the board to include the circuit changes, we have made further tweaks to the PCB pattern itself. The most important is that we completely removed the three top layer tracks which connected Q12, Q13 and Q14 to their supply rails, which were on the bottom side of the board.

That current is now routed entirely through bottom layer tracks, eliminating 30 current-carrying vias, six wire feed-throughs and one signal via (a via makes an electrical connection between tracks on different layers of the PCB).

We have also "tented" all the vias on the board, except for those which require wire feed-throughs to be installed (for robustness under fault conditions). This means that the solder mask layer goes over the vias, exposing as little copper as possible and thus reducing the chance of short circuits when probing around the board.

Some vias have also been moved under components, further ensuring that you can't accidentally make contact with them. For boards without plated through-holes or solder masks, feed-throughs can still be installed in these locations since the components they are under (the 5W resistors) are mounted proud of the PCB anyway.

We also rearranged some components to take account of the range of sizes available. This includes the 220nF 400V capacitor at the output, the 470μF 63V bypass capacitor for the negative rail and the 47μF bipolar input capacitor. There should now be enough space for just about any components with these ratings.

Note that the PCB retains the most important aspect of the previous design: the layout of the current-carrying tracks results in the induced magnetic fields being almost perfectly cancelled, keeping the distortion low even with a high output power. The updated output filter also improves the output-current magnetic field cancellation, reducing high-frequency distortion by around 20%.

Better connectors

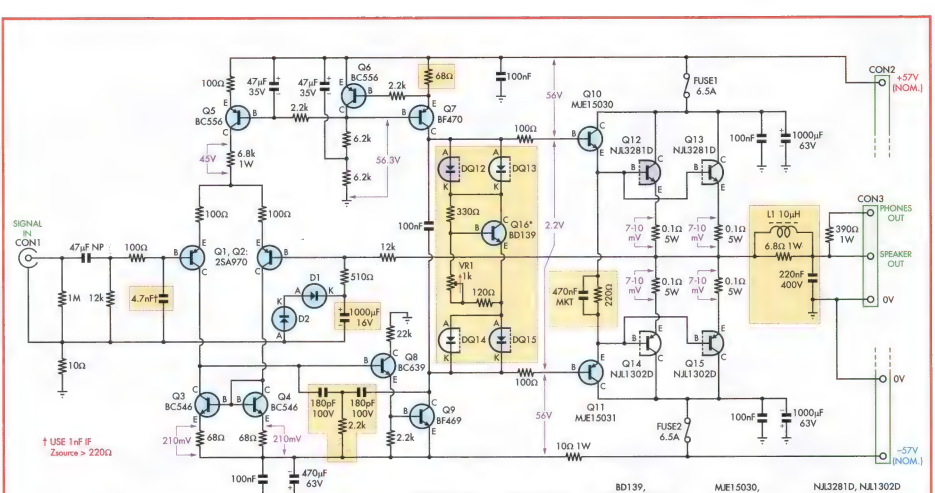
For the Mk.3 design, we have also changed the connector arrangement. All connectors are now pluggable, making it easier to install and remove the module and simplifying testing and repair.

Making reliable connections to a terminal block can be awkward with the module inside a case. More than once we thought we'd made a solid connection but then found that we could easily pull the wire out. The new connectors eliminate that problem.

We have replaced the signal input terminal block with a right-angle RCA socket. For the power input and speaker/headphone outputs, we are now using Molex "Mini-Fit Jr" plastic locking connectors (in horizontal or vertical format). The power connector has three keyed pins and the speaker/headphone connector has four keyed pins, so that they can't be swapped around or connected backwards.

The Mini-Fit Jr connectors are rated at 9A per pin, which is sufficient for this application.

In addition, the final version of the PCB (not shown here) can also accept



SC ULTRA-LD MK.3 200W AMPLIFIER MODULE

Fig.9: the complete circuit diagram for the Ultra-LD Mk.3 amplifier. Changes from the Mk.2 circuit are highlighted with yellow boxes. We have improved the output stage bias circuit and the compensation network, while a new driver emitter resistor configuration speeds output transistor switch-off, reducing distortion. A larger feedback capacitor (1000µF) lowers noise and extends the bass response. In addition, L1 has been increased from 6.8µH to 10µH which partially cancels the magnetic field produced by the output current, reducing high-frequency distortion.

vertical connectors in two locations (ie, a vertical RCA socket for the signal input and a vertical 3-way Mini-Fit Jr connector for the power input). These let you build a stereo amplifier, with the two amplifier modules mounted on either side of the case. The new, slimmer power supply board (described next month) can then fit between them.

Heatsinking

As stated, the additional transistor for the V_{BE} multiplier is located on the heatsink between the two driver transistors (Q10 & Q11). To make room, the output transistor pairs are now closer together. This allows us to position the mounting holes for all transistors so that they fall in between heatsink fins, with the board centred on the heatsink.

It is therefore no longer necessary to blind-tap the mounting holes or to offset the board from the centre of the heatsink if the transistor machine screws are fastened with nuts, as was the case with the Mk.2 design.

Note that if you plan to run the amplifier at continuous high power levels (100W or more) into a 4Ω load then it will probably be necessary to use a larger heatsink (with lower thermal resistance to the air) and/or fan-forced cooling. If driven at full power (200W) into a 4Ω load continuously, the heatsink becomes too hot to touch even in free air (70°+) and this will be even worse if it is mounted in a chassis with limited ventilation.

For continuous high power levels into 8Ω, a larger heatsink is also a good idea although it may not be strictly necessary if the ventilation is good.

Note that in either case (4Ω or 8Ω), for music program material, if the amplifier is not driven into clipping then heatsinking should not be an issue. This is because even heavily compressed pop music typically has a dynamic range of at least 10dB, so even if the peak power is close to maximum, the average power will be significantly less.

Load lines

When we described the Ultra-LD Mk.2, we did not publish any load line curves. Such graphs show the range of transistor currents and dissipations that can occur with speaker loads (resistive and reactive) and the Safe Operating Area (SOA) of the transistors in the amplifier.

The relevant load lines and the SOA curve for the Mk.3 are shown in Fig.6.

By comparing the SOA curve for a pair of ThermalTrak transistors to reactive load lines for typical 4Ω and 8Ω loudspeakers, we can determine whether the transistors are likely to exceed their ratings during periods of high power output. If they can be driven beyond the safe operating area, the output transistors may be destroyed by second breakdown.

Second breakdown is a phenomenon which can occur in bipolar transistors, where high temperature and dissipation lead to thermal runaway in a small area on the silicon die, ultimately resulting in the silicon melting. We need to ensure that this is not possible under normal conditions.

As you can see from Fig.6, the load lines for 4Ω and 8Ω resistive and reactive loads are within the safe operating area. This curve is computed based on the ThermalTrak transistor data sheets and assuming that no single output transistor is required to carry more than 55.6% of the total load current. It is specified for signal durations of one second.

Since the reactive load curves are within the SOA then the amplifier should be quite robust. Unless the load impedance is dramatically less than we are assuming (eg, due to a short circuit at the output), the power transistors should be safe from destruction.

All in all, plotting the load lines gives us a reasonable idea of how close to the limits we are pushing the power transistors.

Circuit description

Let's now look at how the circuit works in more detail – see Fig.9.

As shown, the input signal is applied to CON1 and is coupled to the base of PNP transistor Q1 by a 47μF non-polarised capacitor. The intervening RC filter (100Ω/4.7nF) attenuates any supersonic signals present, eg, switching artefacts from a DAC. The 12kΩ resistor provides the bias current for Q1's base.

PNP transistors Q1 and Q2 are the differential input pair, with Q1's base being the non-inverting input of the amplifier and Q2's base being the inverting input. These are configured as a "long tail pair", fed with current by PNP transistor Q5, which is configured as a current source. The 100Ω resistor at its emitter sets the current through this stage to around 6.5mA (0.65V/100Ω).

Some of this current flows through Q1's collector-emitter junction and the rest flows through Q2's. How the current is split depends on the difference in voltage between the two bases. Most of this current then flows through NPN transistors Q3 and Q4, which are configured as a current mirror.

This current mirror keeps the current through Q3's collector-emitter junction equal to the current through Q4's, so any difference in the current through Q1 and Q2 must then flow to the base of Q8. Thus the current to Q8 is proportional to the difference in voltage between the bases of Q1 and Q2, ie, the two amplifier inputs.

The 100Ω resistors at the emitters of

WARNING!

High DC voltages (ie, ±55V) are present on this amplifier module when power is applied. **In particular, note that there is 110V DC between the two supply rails.** Do not touch the supply wiring (including the fuseholders) when the amplifier is operating, otherwise you could get a lethal shock.

You Must Use Good-Quality Transistors

To ensure published performance, the 2SA970 low-noise transistors must be from Toshiba. Be wary of counterfeit parts.

We recommend that all other transistors be from reputable manufacturers, such as NXP Semiconductors, On Semiconductor, ST Microelectronics and Toshiba. This applies particularly to the MJE15030 & MJE15031 output driver transistors.

During the course of our testing, we came across some BC556 transistors which, when used in the amplifier, resulted in excessive distortion. Despite this, their h_{FE} figure tested as normal. Replacing them with a different batch returned the distortion to normal. Use good-quality transistors throughout to guarantee good performance.

Parts List

1 double-sided PCB, code 01107111, 135 x 115mm
1 black anodised aluminium heatsink, 200 x 75 x 45mm (L x H x D)
4 M205 PCB-mount fuse clips
2 6.5A M205 fast-blow fuses (F1,F2)
1 10μH air-cored inductor (L1) (or 1 20mm OD x 10mm ID x 8mm bobbin and 2m of 1mm diameter enamelled copper wire, plus one length of 10 x 20mm diameter heatshrink tubing)
1 1kΩ multi-turn vertical trimpot (VR1)
2 TO-220 mini flag heatsinks, 19 x 19 x 9.5mm
5 TO-220 silicone insulating washers
4 TO-264 or TOP-3 silicone insulating washers
2 transistor insulating bushes

Screws, nuts, spacers & washers

4 M3 x 9mm tapped spacers
7 M3 x 20mm machine screws
2 M3 x 10mm machine screws
8 M3 x 6mm machine screws
9 M3 nuts
9 M3 flat washers

Connectors

1 black PCB-mount switched RCA connector, or one vertical PCB-mount RCA connector (CON1)
1 Molex Mini-fit Jr 3-pin right-angle PCB-mount male socket (Element14 order code 9963545); OR one vertical PCB-mount Mini-fit Jr male socket (Element14 order code 9963570) (CON2)
1 Molex Mini-fit Jr 4-pin right-angle PCB-mount male socket (CON3, Element14 order code 9963553)
1 Molex Mini-fit Jr 3-pin female line plug (CON2, Element14 order code 9963480)
1 Molex Mini-fit Jr 4-pin femal line plug (CON3, Element14 order code 9963499)
7 Molex Mini-fit Jr female pins (for CON2 & CON3, Element14 order code 9732675)

Semiconductors

2 2SA970 low-noise PNP transistors (Q1,Q2)
2 BC546 NPN transistors (Q3,Q4)
2 BC556 PNP transistors (Q5,Q6)
1 BC639 NPN transistor (Q8)
1 BF470 or 2SA1837 PNP transistor (Q7)
1 BF469 or 2SC4793 NPN transistor (Q9)
1 MJE15030 NPN transistor (Q10)
1 MJE15031 PNP transistor (Q11)
2 NJL3281D NPN ThermalTrak transistors (Q12,Q13)
2 NJL1302D PNP ThermalTrak transistors (Q14,Q15)
1 BD139 NPN transistor (Q16)
2 1N4148 signal diodes (D1,D2)

Capacitors

2 1000μF 63V electrolytic
1 1000μF 16V electrolytic
1 470μF 63V electrolytic
2 47μF 35V electrolytic
1 47μF non-polarised (NP) electrolytic
1 470nF 63V MKT
1 220nF 400V MKT
5 100nF 63V MKT
1 4.7nF 63V MKT
2 180pF 100V polypropylene (Rockby Stock No 36350)

Resistors (0.25W, 1%)

1 1MΩ	1 220Ω
1 22kΩ	1 120Ω
2 12kΩ	6 100Ω
1 6.8kΩ 1W	3 68Ω
2 6.2kΩ	1 10Ω 1W
4 2.2kΩ	1 10Ω 0.25W
1 510Ω	1 6.8Ω 1W
1 390Ω 1W	4 0.1Ω 5W
1 330Ω	2 0Ω

2 68Ω 5W (for testing)

Q1 and Q2 are "emitter degeneration resistors" which provide some local negative feedback, increasing their linearity at the cost of reduced gain (which in turn reduces the overall open loop gain of the amplifier). The 6.8kΩ resistor simply reduces the dissipation in Q5. The 68Ω emitter resistors for Q3 and Q4 improve the accuracy of the current mirror.

Voltage amplification stage

The circuitry described above comprises the first stage of the amplifier and as explained, it converts the differential input voltage into a proportional current. This current is then converted back to a single-ended voltage, relative to the negative rail, by the following stage (the "voltage amplification stage" or VAS). This consists primarily of NPN transistors Q8 and Q9 as well as PNP transistor Q7.

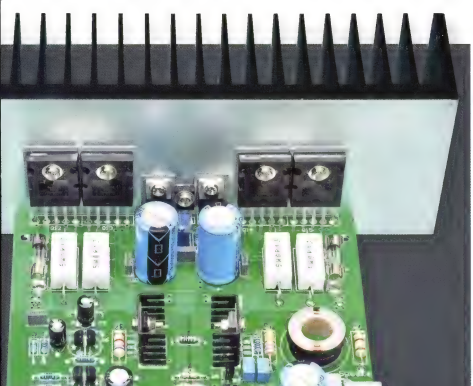
NPN transistor Q8 amplifies the current from the previous stage and feeds it to NPN transistor Q9. Together they form a compound transistor similar to a Darlington, which is set up as a common-emitter amplifier. PNP transistor Q7 is the current source load for this amplifier and the standing current is set to around 9.5mA by the 68Ω resistor (0.65V/68Ω). This current flows from Q7, through the output stage bias network (DQ12-DQ15 and transistor Q16) and thence to Q9.

This common-emitter amplifier converts the current delivered to the base of Q8 into a voltage, at Q9's collector. This voltage is then proportional to the input voltage differential at the base of Q1 and Q2.

Transistor Q6 provides the negative feedback for both current source transistors (Q5 and Q7), regulating the current through them. The two 6.2kΩ resistors, in combination with the 47μF capacitor, form a bootstrapped current sink which turns on both Q5 and Q7. Once the right amount of current is flowing through each, Q6 turns on and reduces the base current to both in order to maintain it at that level.

The two 180pF capacitors and the 2.2kΩ resistor between Q8's base and Q9's collector are the compensation network described earlier, which takes the place of the traditional Miller capacitor. This reduces open loop gain at high frequencies by reducing the gain in this stage, as well as linearising the operation of Q8 and Q9.

The negative supply rail for this stage and for the previous (input) stage is filtered using a 10Ω resistor and a 470μF capacitor. This low-pass filter prevents 100Hz power-supply ripple from coupling into the signal path, especially when the output power is



Another view of the completed Ultra-LD Mk.3 amplifier module. The full constructional details will be published next month.

high. It's the negative rail that requires filtering most of all because the output voltage of the VAS common-emitter amplifier is relative to this.

Output stage

The output stage is a current buffer/unity gain voltage follower formed from two complementary emitter-followers. These are arranged in Darlington configuration, with a single driver transistor for each half (Q10 and Q11) providing current to the bases of two output transistor pairs (Q12/Q13 and Q14/Q15 respectively).

There is a 100Ω resistor in series with the base of each driver transistor, to limit current in the event of a (brief) output short circuit. The voltages at the bases of the two driver transistors are controlled by the common-emitter amplifier in the previous stage. The DC voltage between them is set by the bias generator described earlier.

The 100Ω resistors also function as RF "stoppers" which reduce the possibility of parasitic oscillation in the emitter-follower output stages.

The class-A amplifier (VAS) current passes through the bias generator and the voltage across it is determined by the forward voltage of the two ThermalTrak diodes which have the lowest forward voltage within each pair, plus the voltage across the V_{BE} multiplier. The voltage across the V_{BE} multiplier is roughly Q16's base-emitter voltage multiplied by a factor set by VR1. This bias voltage varies with the junction temperatures of Q10-Q15.

The 0.1Ω emitter resistors for Q12-Q15 force each pair (Q12-Q13 and Q14-Q15) to share the load current, as well as providing a small amount of current feedback.

RLC filter

After the output stage is the RLC filter consisting of a 10μH air-cored inductor, 6.8Ω resistor and 220nF capacitor. This isolates the amplifier circuitry from any load reactance (capacitance or inductance) caused by the cabling or loudspeakers.

The 10μH inductor presents a low impedance to audio-frequency signals but a high impedance at supersonic frequencies, at which the amplifier might oscillate. Therefore it isolates the amplifier from the load at critical frequencies where the load's reactance may cause the amplifier to oscillate.

The parallel 6.8Ω resistor acts as a "snubber", preventing the output filter from oscillating in response to signal pulses from the amplifier.

The inductor also prevents any RF signals picked up by the speaker leads from being coupled to the base of Q2 where they may be rectified to an audio frequency signal. The 220nF capacitor, in combination with the inductor and resistor, presents the amplifier with a constant load to high frequencies and keeps the output impedance low at high frequencies, even if no speaker is connected. This ensures that oscillation can not occur.

Any output cable capacitance will be swamped by the 220nF capacitor across the output. This filter arrangement was developed by A.N.Thiele (Load Circuit Stabilising Network for Audio Amplifiers, Proceedings of the IREE 299, September 1975).

Power for the output stage is filtered by 1000μF and 100nF bypass capacitors across each rail. If an output transistor fails, one or both of the 6.5A fuses will blow, protecting the power supply.

Loudspeaker protection

Note that it is necessary to connect a loudspeaker protection module between the amplifier and speaker terminals, so that the load is disconnected in the event of an amplifier failure.

Failures usually cause the output to be connected directly to one or other of the ±57V supply rails and unless a protection module is present to immediately disconnect the loudspeaker, it may be damaged and quite possibly catch fire due to the resulting high current flow through the voice coil.

More to come

That's all we have space for this month. Next month, we will describe how to assemble, test and adjust the amplifier module and also present an updated version of the power supply board. That article will also include some suggestions for putting it all together in a case, as a mono or stereo power amplifier.

Finally, for those who have already built an Ultra-LD Mk.2 module, don't despair. We plan to present a small adaptor board which will allow you to fully upgrade its performance to the Mk.3 standard. SC

PRODUCT SHOWCASE

Vehicle "event" recorder records video, location, time and more!

How often have you thought "where's a camera when you really need one . . ." when something happens in your car! It may be an accident, it may be road rage, it may be any one of dozens of things. Now you can "capture the moment" with this new event recorder from Jaycar Electronics.

Fleet owners, taxi companies, delivery vehicles – even the private motorist can benefit from having a record of vehicle movements and any incidents that occur.

It's about the size of a GPS unit – and in fact has GPS built in – but this device will record any incident, inside or outside the vehicle (depending on mounting) along with a range of parameters such as the vehicle's position, time and so on.

It's triggered automatically by a sudden change in vehicle speed (or can be turned on manually) and writes the data to an SD card. You can elect to keep the information indefinitely by inserting a replacement card, or if you wish the data will over-write the existing information. Depending on the size of the SD card, several hours of video and data can be stored (it supports up to 16GB SD cards).

Video resolution is 640 x 480 @ 30 frames per second and the field of view is 120°. Infrared LEDs allow night scenes to be captured and there is a video output for an external monitor.

It's normally powered by a cigarette lighter plug but there is also a backup NiMH battery just in case.

Recommended retail price is $249.00 (QV-3798).

Contact:
Jaycar Electronics (all stores)
PO Box 107, Rydalmere NSW 2116
Order Tel: 1800 022 888 **Fax:** (02) 8832 3188
Website: www.jaycar.com.au

Optiview XG network analysis tablet

Fluke Networks' new OptiView XG network analysis tablet is claimed to provide the fastest solutions for network and application problems for both wireless and wired access, anywhere in the network.

The tablet expedites network and application problem solving by automating root cause analysis and providing guided troubleshooting to address problem areas.

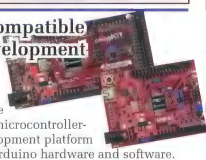
It is an instant, integrated window into organisations' network in a tablet form factor, that you can take from the data centre, to the production floor, to the office desktop.

The OptiView XG is designed to provide a wide range of functionality necessary to adapt to the dynamic and diverse networks of today through various features.

It has a bright, easy-to-to read screen and features customisable dashboards that can be personalised for each user or help transform data into reports for employees at all levels of the organisation, from technicians to managers. More information is available on the company website.

Contact:
Fluke Australia Pty Ltd
Unit 26, 7 Anella Ave, Castle Hill, 2154
Tel: (02) 8850 3333 **Fax:** (02) 8850 3300
Website: www.flukenetworks.com/au

First Arduino-compatible 32-bit micro development platform



Microchip Technology Inc and Digilent, Inc. have launched the first 32-bit microcontroller-based, open-source development platform that is compatible with Arduino hardware and software.

The chipKIT platform is the first and only 32-bit Arduino solution in the industry to enable hobbyists and academics to easily and inexpensively integrate electronics into their projects, even if they do not have an electronic engineering background.

The platform consists of two PIC32-based development boards and open-source software that is compatible with the Arduino programming language and development environment.

The hardware is compatible with existing 3.3V Arduino shields and applications, and can be developed using a modified version of the Arduino IDE and existing Arduino resources, such as code examples, libraries, references and tutorials.

The boards start at US$26.95 each. A video can be viewed online at www.microchip.com/get/D268.

Contact:
Microchip Technology Australia
PO Box 260, Epping, NSW 1710.
Tel:(02) 9868 6733 **Fax:**(02) 9868 6755
Website: www.microchip.com

5km 5GHz 200MBit/s Data Link from WiFi Products

Mikrotik's new SXT 5HnD is a low cost, high-speed 5GHz wireless device ideal for setting up a point-to-point data link with fast throughput. Dual-polarisation 802.11n and Nv2 TDMA technology help to achieve a 200Mbit real throughput speed.

It features a solid all-in-one design, with a ready-to-mount enclosure and built-in antenna. Powered by Mikrotik's RouterOS, it is also a most advanced router, bandwidth controller and firewall.

The SXT has signal-strength LED indicators making it easy to install and align. There's also a USB 2.0 port and voltage and temperature monitors so you can keep an eye on the system remotely.

This product has huge potential, ranging from extending your LAN to provide internet access, remote monitoring, IP camera surveillance, machinery control, etc on farms, stock monitoring in large warehouses and factories and so on. Or it can be an viable alternative when running a cable is just too difficult or expensive.

The 16dBi antenna can give you up to 5km range while the SXT itself measures in at only 140mm diameter and 56mm deep.

Retail price is less than $230 a pair delivered within Australia.

Contact:
WiFi Products
2/24 Windorah St, Stafford Qld 4053
Tel: (07) 3356 0588
Website: www.wifiproducts.com.au

EFM32 Tiny Gecko Starter Kit

Energy Micro has released a starter kit for its ARM Cortex-M3 based EFM32 Tiny Gecko microcontrollers.

Referenced EFM32TG-STK3300 and selling at US$69, the kit provides users with all the functionality that's needed to create ultra low power system designs consuming a fraction of the energy of systems using rival microcontrollers.

Achieving an active mode current consumption of only 160µA/MHz, the energy friendly EFM32TG840 microcontroller featured in Energy Micro's latest kit is the largest in a family of 23 Tiny Gecko devices now in full production. The starter kit includes a 8x20 segment LCD supported by Tiny's sub µA LCD controller and a selection of light, touch and motion sensors, backed by the MCU's innovative low energy sensor (LESENSE) interface.

Tiny's LESENSE interface with 'wake-on-touch' capability runs independently of the Cortex-M3 core and enables a mix of up to 16 resistive, capacitive or inductive sensors to be autonomously monitored while the microcontroller remains in its 900nA deep sleep mode. Other low power peripherals ofered by the kit's MCU include a 150nA low energy UART and a 350µA 1MSPS 8-channel 12-bit ADC.

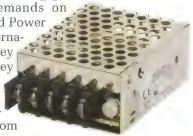
The starter kit provides a comprehensive choice of GPIO pins, serial communication ports and debug connections.

To support the development of the most energy efficient application code, the Tiny Gecko starter kit also integrates Energy Micro's unique Advanced Energy Monitoring system (AEM), enabling system current consumption and voltage to be accurately viewed in real time, allowing code to be debugged for adverse energy drains.

Visualisation and analysis of the starter kit system's energy consumption data is via energyAware Profiler, one of a comprehensive selection of software tools and resources accessible through Energy Micro's free-to-download Simplicity Studio. Providing immediate access to and updates on all the software tools, product documentation and other resources needed in the development of EFM32 Gecko microcontroller systems, Simplicity Studio aims to dramatically reduce embedded development times.

Contact:
APEX Electronics Ltd
PO Box 2357, 175 Vivan St, Wellington, 6140, NZ
Tel: (0011) (64) 4 974 8943 **Fax:** (64) 4 385 3483
Website: www.apexelec.co.nz

RS Branded Power Supplies



With the increasing demands on power supplies, RS Branded Power Supplies are excellent alternatives to meet your needs. They will help you in saving money without compromising on quality.

The range of enclosed supplies offer power outputs from 15W to more than 1500W with efficiencies ranging from 77% right up to 91% for the largest supplies.

Contact:
RS Components
25 Pavesi St, Smithfield NSW 2164
Tel: (02) 9681 8558 **Fax:** (02) 9681 8614
Website: www.rsaustralia.com

Amalgen's range now made by Dyne

Dyne Industries, designers and manufacturers of custom-made transformers, power supplies and wound components, has taken over the manufacturing and sales of the Amalgen range of power supplies and toroidal transformers at the retirement of Amalgen's Frank Choate (who will remain as a consultant).

The acquisition of the Amalgen products extends Dyne's range of transformers and light electronic products into new markets. Amalgen power supplies have a high reputation in the mining and manufacturing industries and this matches the high quality of the Dyne products. The range now covers AC and DC power supplies, DC UPS's single & 3 phase transformers, audio transformers, inductors, specialty wound components and light electronic assembly.

Contact:
Dyne Industries Pty Ltd
41 Barry St, Bayswater, Vic 3153
Tel: (03) 9720 7233 **Fax:** (03) 9720 7551
Website: www.dyne.com.au

This little device could save your life . . .

You don't want to be caught in a storm, especially if you are on a sports field, out boating, bushwalking or working in the open, on the farm or anywhere else where there is minimum shelter. If there is even a *risk* of a storm, take this Lightning Detector with you before venturing outdoors.

Lightning Detector

by John Clarke

While most of us love the wide open spaces, they are definitely not the place to be if a thunderstorm is on the way. If there is a lightning strike nearby you could be in big danger of death or injury. And you don't have to be hit directly – induction can kill you and so can the voltage gradient across the ground in the vicinity of a lightning strike.

Our Lightning Detector can warn you of an approaching lightning storm and provides valuable time to take shelter safely indoors. And even if you're not outdoors it can give you warning to disconnect vulnerable electrical appliances from the 230VAC mains supply. It provides audible and visual indication to warn of approaching thunderstorms.

Lightning damage to electronic appliances

Many people do not realise how vulnerable electronic equipment can be in a thunderstorm, even if it is not close by. Service organisations report a big surge in repair jobs after storms and just about all of this could be avoided simply by switching off and removing power plugs from the wall socket.

Those appliances especially at risk include microwave ovens, TV sets, satellite receivers, mains powered computers (especially those also connected to the phone lines via a modem), washing machines and dryers.

They should not be just switched off at the power point but the mains plug should be removed from the socket. TV antenna and satellite dish connections should be disconnected too. Many ovens incorporate electronic timers and power to these can be switched off at the "fuse" box.

Apart from mains-powered computers, devices that are particularly prone to damage are fax machines and cordless telephone base stations. It is the fact that they are connected to both the 230VAC mains and the telephone wiring that provides a double whammy. During a big thunderstorm they should be disconnected both from the phone line and the mains power.

Of course, it is well known that any phones (apart from mobiles and cordless models) should not be used during a thunderstorm.

So what to do?

To get a warning of imminent thunderstorms, you need the SILICON CHIP Lightning Detector. It is a pocket-sized unit that provides visual indication using a flashing LED and sounds an audible tone whenever lightning occurs in your area. The greater the number of lightning strikes, the more LED flashes and audible tone bursts are produced.

For portable use it is powered with two alkaline AA cells, Battery life should be at least 1000 hours. For indoor use, you can use a 6V-12V DC supply, such as a plugpack. One resistor needs to be chosen according to the DC supply voltage. When the external power supply is connected to the jack the socket, the AA cells are automatically disconnected from the circuit.

The principle of operation is based on detection of the broad-spectrum electromagnetic emissions produced by lightning strikes. This is readily detected by a simple AM (amplitude modulation) radio receiver.

If you've ever been anywhere near an electrical storm with an AM radio turned on, you'll have heard the crashes (static) of lightning strikes. Very large strikes can be heard from a considerable distance away.

We use a single AM radio IC which comprises a RF (radio frequency) amplifier, detector and AGC (automatic gain control). This was originally available in 1984 from Ferranti Semiconductors as the ZN414Z but replaced by the MK484, now also obsolete.

We have used the modern equivalent, the TA7642. It operates from a 1.2 to 1.6V supply and covers from 150kHz to 3MHz. This includes the normal AM radio broadcast band (530kHz to 1.6MHz) but for our purposes, we are not concerned with listening to broadcast radio stations. We simply monitor the whole spectrum covered by the AM radio chip.

Block diagram

The general arrangement of the Lightning Detector is shown in the block diagram of Fig.1. IC1 receives signals from a pickup coil. In an AM radio this pickup coil would normally be tuned to a particular frequency using a variable tuning capacitor.

We want to monitor a wide frequency range and so the coil is left un-tuned. IC1's output signal is noise bursts from lightning.

Output from IC1 is typically 15mV with a tuned coil but is around 2mV with the un-tuned coil. This signal is amplified using transistor Q2 and a sensitivity control sets the level applied to the following pulse extender comprising IC2 and diode D3. When lightning is detected, a noise-burst triggers the pulse extender.

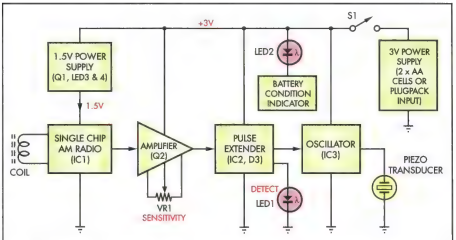


Fig.1: the block diagram of the Lightning Detector. The early part looks similar to a radio receiver – which of course it is – but this radio receiver picks up just one thing: the RF pulse from a lightning strike within range.

The pulse extender produces a 200ms pulse and this lights the "detect" LED1. The pulse extender is necessary because the lightning strike pulses are too short in duration to be noticed as a flash from the LED.

IC3 is an oscillator that runs for 200ms each time the pulse extender produces a low signal and the resulting 4kHz tone burst drives the piezo transducer which is resonant at that frequency.

Circuit details

The full circuit is shown in Fig.2. As mentioned, IC1 is the TA7642 AM radio chip while CMOS 555 timers are used for the pulse extender IC2 and for 4kHz oscillator, IC3. The circuit is powered from 3V but it will operate down to 2V.

A 1.5V regulated supply powers IC1 while the amplifier, pulse extender (IC2) and the oscillator (IC3) are driven from the 3V supply.

While most of the circuit is powered from the 3V supply rail, IC1 needs to be operated at between 1.2 and 1.6V. To provide for this we use a voltage regulator comprising transistor Q1 plus infrared LED3 & LED4. These develop a forward voltage of approximately 1V each which is remarkably constant over a wide range of current. Tests of several infrared LEDs from different manufacturers showed that the forward voltage is around 1.09V at 1.6mA current dropping to 0.945V at 160µA, ie, a current range of 10:1.

Stacking two infrared LEDs in series provides a reasonably stable 2V reference. The LEDs are fed via a 2.2kΩ resistor from the 3V supply and the 2V reference drives the base of transistor Q1. This acts as a current buffer to supply IC1 with about 1.4V. This varies from 1.46V with a 3V supply down to 1.287V with a 2V supply.

IC1 is connected to the 1.4V supply via the 470Ω AGC resistor at its output pin. A 100nF decoupling capacitor at the output sets the high frequency rolloff to 4kHz.

One end of the pickup coil L1 is connected to the high impedance (around 3MΩ) input of IC1 while the other end is grounded via a 100nF ceramic capacitor. There is no parallel capacitor across

Features

- Portable
- Battery or external power supply
- Visual and audible lightning indication
- Sensitivity control
- Battery condition indicator
- Reverse supply protection

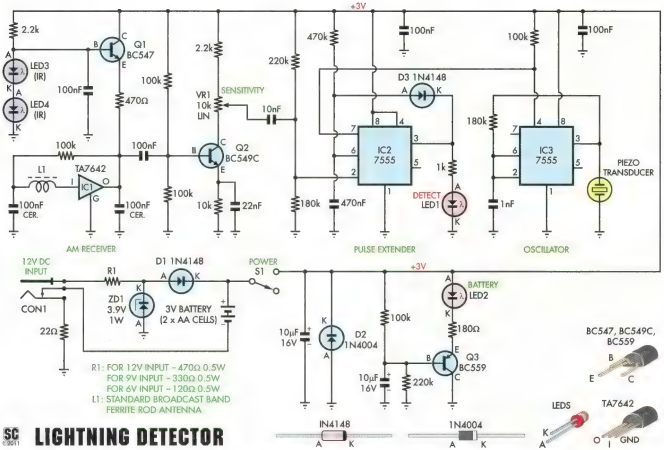


Fig.2: the three main functional areas of the circuit diagram are labelled the same as block diagram to enable you to trace the circuit operation through. As mentioned in the text, resistor R1 needs to selected depending on the DC power supply you use – it can handle anything from 6 to 12V. The battery supply is nominally 3V but it will operate down to 2V.

L1. This means that the coil is un-tuned and will have a broadband response. Bias for the input of IC1 comes from a 100kΩ resistor connected to its output.

IC1's output is AC-coupled to the following common emitter amplifier, Q2. This has its emitter resistor bypassed with a 22nF capacitor to provide a gain of about 50 for frequencies above about 723Hz. Q2's collector load comprises the 10kΩ potentiometer VR1 and a 2.2kΩ resistor. VR1 is the sensitivity control.

IC2 and IC3 are CMOS 555 timers and most manufacturers of these devices state that their version will operate down to 2V or less. These include the Intersil ICM7555IPA, Texas Instruments TLC555CP, ST Microelectronics TS555CN and National Semiconductor LMC555CN. The NXP (founded by Philips) ICM7555CN guarantees operation at 3V over full automotive temperatures. However, performance graphs show operation with a 2V supply at –55° C, 25°C and 125°C. Also samples of the NXP ICM7555CN operate successfully at 2V and we are inclined to assume that this IC does also operate at 2V.

Make sure you do not use bipolar 555 timers such as the LM555CN or the TL555CP as these typically require 4.5V or more for operation.

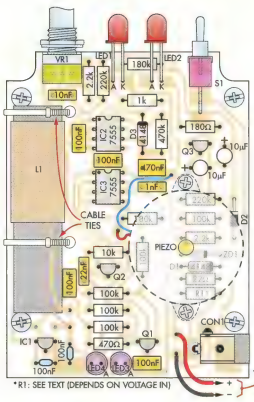
IC2 is the pulse extender which is set up as a monostable timer. Before triggering occurs, pin 3 is close to 0V and the 470nF capacitor is held discharged at about 0.6V above 0V by diode D3. Pin 2 is held at 45% of the 3V supply, ie, at +1.35V, using the 220kΩ and 180kΩ voltage divider resistors.

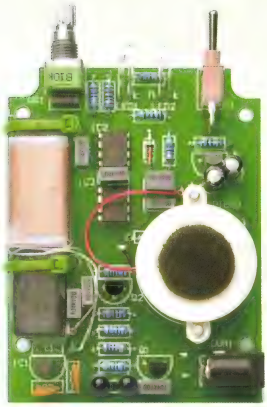
Triggering occurs when the noise signal fed to pin 2 pulls it below +1V. This sets pin 3 high and diode D3 is then reverse biased. The 470nF capacitor then begins to charge via the 470kΩ resistor. During this time, LED1 is lit (driven from pin 3) When the voltage across the 470nF capacitor reaches 2/3 of the supply voltage, pin 3 goes low and the 470nF capacitor is discharged via diode D3.

This is an unconventional monostable timer arrangement. Normally pin

Specifications

Supply voltage:	3V (2 x AA cells) [will operate down to 2V] Plugpack: 6 to 12VDC at 30mA
Current Consumption:	Battery operation 1.5mA at 3V, 1mA at 2V, DC plugpack operation 17mA at 12V
Battery life:	Typically 1000h with Alkaline cells
IC1 supply:	Typically 1.46V with 3V supply, 1.28V with 2V supply
Battery voltage indication:	Down to 2V
Strike indication duration:	200ms
Transducer frequency drive:	4kHz
Frequency detection band:	150kHz to 3MHz





End Panel Drill Guide

Fig.3: everything (except the batteries) mounts on a single-side PCB. The component layout is shown above and, with the same-size photo at right, is self-explanatory. At right is Fig.4, the drilling guide for the end panel. There is no labelling on this panel; all controls are labelled on the front panel. Millimetre dimensions are the hole diameter required at each position.

7, the discharge, would be connected to pin 6 and would discharge the 470nF capacitor instead of using diode D3. Using D3 to discharge the capacitor frees pin 7 to perform another task. Because it can sink (pull down) to 0V, it is suitable for use as a reset control for the following oscillator, IC3.

IC3 is connected in astable (free-running) mode, running at about 4kHzm to drive the piezo transducer. It is held in the reset condition, with its pin 4 pulled low by pin 7 (discharge) of IC2, when IC2 is not timing.

Power supply

As already mentioned, the Lightning Detector is powered from two AA-cells or a low voltage plugpack supply. When running from the AA cells, current flows via the closed contact in the power connector (CON1) and through the 22Ω resistor to the 0V supply. This resistor is included to prevent excess current if the cells are inserted back-to-front. When the cells are correctly inserted, the 22Ω resistor produces a minimal voltage drop (normally less than 33mV and less than 100mV with the detect LED lit).

When running from a DC suppy, the AA cells are disconnected via CON1 (as noted above) and the incoming supply is regulated down to 3.9V using zener diode ZD1 and resistor R1. The value of this resistor depends on the DC supply voltage – anywhere from 6V to 12V will be suitable, with resistor values of 120Ω (6V), 330Ω (9V) or 470Ω (12V). The negative supply connects to the circuit ground via the 22Ω resistor.

Diode D1 reduces the 3.9V zener voltage supply to about 3.3V. We could have used 3.3V zener diode on its own without D1. However, we want to be able to run the circuit from two AA cells that provide a 3V supply. If a 3.3V zener diode were used, the cells would be discharged via the zener diode. So by including diode D1, current is prevented from flowing through the zener diode. The zener voltage is increased from 3.3V to 3.9V to compensate for the 0.6V diode drop.

D1 also blocks reverse voltage to the circuit should the 12V supply be connected with reversed polarity. With reverse polarity, zener diode ZD1 is forward biased and clamps the voltage to no more than -0.6V below the 0V supply. D1 stops current flowing through the circuit backwards.

Battery indication

When the power is first switched on, LED2 provides indication of the battery condition. LED2 is driven via PNP transistor Q3 and its base is initially tied to 0V via the 10μF capacitor. With the supply at 3V, Q3's emitter is at about 0.6V and the LED is driven at maximum brightness. That is with about 2.4V (3V-0.6V) across the LED and 180Ω resistor. Assuming a LED forward voltage of 1.8V, this produces a current of about 3mA.

At a lower supply voltage, the initial LED current is less and it will be dimmer. With a 2V supply, LED2 will be barely alight, indicating that the batteries should be replaced.

Parts List – Lightning Detector

1 PCB coded 04107111, 65 x 86mm
1 remote control case 135 x 70 x 24mm (Jaycar HB5610 or equivalent)
1 panel label 50 x 114mm
1 miniature PC mount SPDT toggle switch (Altronics S1421 or equivalent) (S1)
1 10k log potentiometer, 9mm square, PCB mount (VR1)
1 knob to suit potentiometer
1 switched 2.5mm PCB mount DC socket (CON1)
2 AA Alkaline cells
2 DIP8 IC sockets (optional)
1 tuning coil with ferrite rod (Jaycar LF-1020)
1 piezo transducer (Jaycar AB-3440, Altronics S 6140)
2 6mm spacers
2 M2.5 x 12mm screws
4 6mm self-tapping screws
2 100mm cable ties
6 PC stakes
1 50mm length of red light gauge hookup wire
1 50mm length of black light gauge hookup wire

Semiconductors

1 TA7642 single chip AM radio (IC1) (Wiltronics X-TA7642)
2 7555 CMOS 555 timers (ICM7555IPA, TLC555CP, TS555CN, LMC555CN or ICM7555CN) (IC2,IC3)
2 3mm high intensity red LEDs (LED1,LED2)
2 5mm IR LEDs (LED3,LED4)
1 BC547 NPN transistor (Q1)
1 BC549C NPN transistor (Q2)
1 BC559 PNP transistor (Q3)
1 3.9V 1W zener diode (ZD1)
2 1N4148 switching diodes (D1,D3)
1 1N4004 diode (D2)

Capacitors

2 10µF 16V PC electrolytic
1 470nF MKT polyester
4 100nF MKT polyester
2 100nF ceramic
1 22nF MKT polyester
1 10nF MKT polyester
1 1nF MKT polyester

Resistors (0.25W, 1%)

1 470kΩ	2 220kΩ	2 180kΩ	5 100kΩ	1 10kΩ
2 2.2kΩ	1 1kΩ	1 470Ω	1 180Ω	1 22Ω

1 of 120Ω, 330Ω or 470Ω 0.5W (R1 – see text)

Whatever the supply, LED2 only lights momentarily and as the 10µF capacitor begins to charge via the 100kΩ resistor, it dims and eventually goes out. The 220kΩ resistor across the 10µF capacitor prevents the capacitor charging to any more than 2/3rds the supply. This provides a faster discharge of the capacitor when the supply is switched off. The 220Ω resistor is also used to discharge the capacitor when the supply is off so it is ready to flash the LED when power is reapplied.

Construction

The Lightning Detector uses a PCB measuring 65 x 86mm and coded 04107111. The PCB and components are housed in a plastic case measuring 135 x 70 x 24mm.

Here's how the PCB fits inside the case. The top corners need to be shaped to fit the case mounting pillars but otherwise it's a simple drop-in fit, secured by four self-tapping screws . The two AA batteries which power the unit fit under the moulding at the bottom.

The PC board is designed to mount onto the integral mounting bushes within the box. Make sure the front edge of the PC board is shaped to the correct outline so it fits properly. It can be filed to shape if necessary using the PCB outline shape as a guide.

Begin by checking the PCB for breaks in tracks or shorts between tracks or pads. Fix any defects, if necessary. Check the hole sizes for the PCB mounting holes and for the cable ties. These are 3mm in diameter.

You can then insert the resistors and use the resistor colour code table to select each value and check each one with a digital multimeter. Then install the diodes; they must be mounted with the orientation as shown. Install the six PC stakes.

IC2 & IC3 can be mounted on sockets or directly soldered to the PCB. When installing sockets and ICs, take care to orient them correctly – as indicated by the notch at one end.

Capacitors can be mounted now. The electrolytic types must be oriented with the shown polarity. Make sure these capacitors are placed on the PCB so their height above the surface is no more than 12.5mm, otherwise the lid of the case will not fit correctly.

Note that while provision is made for a capacitor across the L1 coil, as mentioned earlier one is not used in this circuit.

It is included so that you can experiment with the radio IC by placing a tuning capacitor between the two PC stakes for the L1 coil and placing a fixed value (if required) capacitor to pad out the capacitor range. This will allow the reception of radio broadcast stations.

Audio signal is available at the VR1 wiper. A coupling

Looking end-on shows the two controls and two LEDs which mount on the end panel. Fig.5 (below right) is the same-size front panel artwork which can be photocopied or downloaded and printed, then glued in place.

capacitor (say 100nF or so) is required to connect this signal to an external amplifier.

Mount IC1 and the transistors taking care to place each in its correct place. If you happen to be using a Ferranti ZN414Z from your IC collection for IC1 note that the GND and Out pins are reversed compared to the TA7642. You would have to place the IC in the PCB oriented 180° to that shown on the overlay.

An MK484 has the same pin out as the TA7642. The TA7642 has a greater sensitivity in the lightning detector application compared to the MK484 and so given the choice, we recommend using the TA7642. We did not try a ZN414Z since this is not available.

The potentiometer (VR1) and the PCB-mounted switch S1 can now be soldered in.

LED1 and LED2 mount horizontally but at a height of 6mm above the board surface. Bend their leads 90° at 7mm back from the base of the LEDs, making sure the anode lead is to the left.

L1 is a standard broadcast band coil pre-wound onto a small ferrite rod. There are actually two coils on the rod but only one is used.

Using your multimeter, find the coil that has the greatest resistance. With our prototype, the main winding measured about 11Ω , while the separate antenna winding measured 2Ω . Connect the coil with the highest resistance to the PC stakes.

The ferrite rod is secured to the PCB using a pair of small cable ties.

The piezo transducer is mounted using two 6mm long standoffs and 12mm long M2.5 screws. The screws are inserted from the underside of the PCB, pass through the spacers and tap into the piezo mounting tabs. If you are using a different piezo transducer that has larger mounting holes in the tabs, M3 screws could be used instead to tap into the plastic transducer tabs. Alternatively, two nuts can be used.

Follow the wiring diagram to make the connections from the piezo transducer and battery terminals to the PC stakes on the PCB.

Next, install the battery clips into the battery compartment. The two connected terminals are placed on the right hand side (as you look at the rear of the case with the compartment at the bottom). The spring terminal is placed to the top and raised section to the bottom. For the left side, insert the separate terminals with the spring terminal placed at the lower edge and the raised section to the top.

On the compartment inside bend the two individual terminals to the outside of the compartment. You may need to stretch the contact springs so that the AA cells are held securely between the contacts.

The PCB is secured to the base of the case using four M3 x 6mm screws that screw into the integral mounting bushes in the box. Before fitting them in place, drill out the small front panel for the LEDs, potentiometer and switch. A drill guide is available and is provided with the front panel label. This can be used as a guide as to the drill hole positions.

The panel label for this project can either be photocopied (without infringing copyright) – see fig.5 – or for best results, it can be downloaded from the SILICON CHIP website (www.siliconchip.com.au). Go to the downloads section and select the month and year of publication.

When downloaded, print it onto paper, sticky-backed photo paper or onto plastic film. For protection and long life, paper labels should be covered with either self-adhesive clear film or (as we normally do) hot laminated (laminators and sleeves are very cheap these days and give a tough protective layer!).

If printing on clear plastic film (overhead projector film) you can print the label as a mirror image so that the ink is behind the film when placed onto the panel. Again, this will give the label maximum protection. Once the ink is dry, cut the label to size.

The paper or plastic film is glued to the panel using an even smear of neutral-cure silicone. For plastic film, if you are gluing it to a black coloured panel, use coloured silicone such as grey or white so the label can be seen against the black.

A hole in the panel is required directly above the piezo transducer. This can be first drilled in the plastic lid and then once the panel label is affixed, cut the hole out using a sharp hobby knife.

A small piece of dark fabric or loudspeaker foam (scrounged from an old pair of headphones) can be used to cover the piezo transducer. Also a black bezel over the panel hole can improve the finish of the unit. These are secured with a smear of neutral cure silicone. Our bezel came from the plastic dress plate that sits behind the nut of a Jaycar PS-0192 stereo 6.35mm jack socket.

Additionally, a cut out is required for access to the DC socket. A rat-tail file can be used to make this hole in the lid.

A suitable belt clip for the remote control box is available

RESISTOR COLOUR CODES

	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	1	470kΩ	yellow purple yellow brown	yellow purple black orange brown
❑	2	220kΩ	red red yellow brown	red red black orange brown
❑	2	180kΩ	brown grey yellow brown	brown grey black orange brown
❑	5	100kΩ	brown black yellow brown	brown black black orange brown
❑	1	10kΩ	brown black orange brown	brown black black red brown
❑	2	2.2kΩ	red red red brown	red red black brown brown
❑	1	1kΩ	brown black red brown	brown black black brown brown
❑	1	470Ω	yellow purple brown brown	yellow purple black black brown
❑	1	180Ω	brown grey brown brown	brown grey black black brown
❑	2	22Ω	red red black brown	red red black gold brown
One of the following (R1):				
❑	1	470Ω	yellow purple brown brown	yellow purple black black brown
❑	1	330Ω	orange orange brown brown	orange orange black black brown
❑	1	120Ω	brown red brown brown	brown red black black brown

Capacitor Codes

Value	μF Value	IEC Code	EIA Code
470nF	0.47μF	470n	474
100nF	0.1μF	100n	104
22nF	0.022μF	22n	223
10nF	0.01μF	10n	103
1nF	0.001μF	1n	102

from Altronics. The catalog number is H0349. (Contact www.altronics.com.au).

Testing

Testing can be done with two AA cells or a DC supply. Apply power and check that the power LED momentarily lights when the Lightning Dectector is switched on. Check the supply voltage by measuring across diode D2. This should be around 3V but may differ depending on the state of the cells or the tolerance of the 3.9V zener diode when a DC power supply is used. Voltage across the 22Ω resistor should be about 33mV with a 3V supply or less with a lower voltage supply.

Check supply to IC1 at the emitter of Q1. This should be 1.46V with a 3V supply dropping to 1.287V with a 2V supply.

Adjust the sensitivity control fully clockwise or back off if any indication persists. Test the Lightning Detector as a fluorescent light is being switched on. The switching on of conventional fluorescent tubes will cause the Lightning Detector to give a LED detect and tone indication with each starter attempt to light the tube. Compact fluorescent tubes tend to be indicated with a single flash and tone as the tube lights rapidly.

The sensitivity control is included to prevent the Lightning Detector from producing an indication when there is no lightning. The control is adjusted clockwise for maximum sensitivity to lightning but not so far as to give false detection. SC

What to Do in a Storm

The best idea is to avoid getting caught outside in an electrical storm but sometimes, the best laid plans of mice and men. . . etc.

How far away is the lightning?

Watch for a flash of lightning. Then count or read off your watch the number of seconds until you hear the first crash of thunder (or crack if it is close!). Divide the number of seconds by three and you have a rough distance away that the lightning has struck. Anything less than 1km (ie, 3s) should be regarded as getting very dangerous.

If you cannot get to shelter?

If you are caught outside during an electrical storm, avoid conductors of electricity such as water, trees, poles, golf clubs, umbrellas and metal fences.

If possible, keep away from open spaces (eg, the middle of a sports field) where you will be taller than the surroundings and definitely do not shelter under a tree. Crouch down, keeping your feet close together and wait out the storm. Groups of people should be spread out several metres apart.

It is also a good idea to cover your ears with your hands to avoid hearing damage due to the noise of a close lightning strike.

If possible, take refuge inside a vehicle or building. If inside a vehicle, close the windows and avoid touching the metal of the vehicle. Make yourself less of a target by lying down (eg on the back seat). Keep the vehicle away from trees or tall objects that may fall over in the storm. Avoid fallen power lines.

Inside a building, keep windows and doors closed and keep away from windows, doors and fireplaces. Before the storm, unplug electrical appliances that may be susceptible to lightning damage. These include fax machines, telephones, microwave ovens, televisions and computers. To be doubly safe, unplug any computer communications devices from phone lines or cables (don't forget routers etc).

Avoid using electrical appliances and telephones until the storm has well and truly passed. (However, you can use a mobile phone if you have to – eg, to call for help).

Avoid touching earthed fittings such as water taps, sinks, appliances and so on.

If you are on a boat, keep low, dry, and away from metal conductors. Always check with the Bureau of Meteorology for storm forecasts before going out on a boat. In this way you could avoid boating in a storm. If you are a boat owner, make sure the boat is fitted with lightning protection that directs lightning safely to the water. This will help protect the occupants should they be caught out in a storm and also help protect the boat when left moored.

And if someone near you is struck by lightning?

Avoid the temptation to rush in and help – time is of the essence but there's no point in two people being struck!

As soon as it is safe to do so (ie, the danger has passed), commence standard A-B-C resuscitation. Check their response, clear the airway, and if necessary proceed with CPR.

What? You don't know CPR? Learn it today!

Winter Projects at Jaycar

JULY 2011

Check out the tools for DIY projects on pages 2 & 3.

Look for this icon & SAVE BIG! SAVE

INTELLIGENT VIDEO SURVEILLANCE (IVS) 4 CHANNEL DVR KIT

Supplied with 500GB HDD

Make your security measures smart with the use of the Intelligent Video Surveillance (IVS) DVR kit. This DVR kit incorporates a human motion detection camera and three IR colour CCD cameras. Once the motion detection camera detects motion a push notification is sent to your smart phone, enabling you to look at live footage of the intruder as the incident happens. Push notifications are supported for most Smart Phones using the downloadable surveillance app. You can also monitor via Ethernet or Internet connections.

See website for more details.

NEW

DVR

- Four channel split-screen or single channel switching display
- USB 2.0 interface for external backups/mouse
- Motion trigger alarms
- Input/Output: 4-ch input/ 1-ch output
- Video compression: H.264
- Mains power supply included
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Standard Colour CCD Camera

- Infrared LEDs for day/night capability
- Weatherproof IP67 rated housing with integrated mounting bracket
- Resolution: 520 TV Lines
- Effective range: up to 15 metres
- Dimensions: 90(D) x 60(Dia)mm

MORE INFO AVAILABLE ONLINE

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Human Detection Colour Camera

- Push notifications to mobile (via DVR)
- Resolution: 520 TV Lines
- Effective range: up to 15 metres
- Dimensions: 90(W) x 145(D) x 30(H)mm

QV-8110

View live or recorded footage on a 3G phone or iPhone

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- Resolution:420 TV Lines
- Power required: 12VDC

Mini Colour CCD Camera

- Lens: 3.6mm
- Dimensions: 36(W) x 36(H) x 15.9(D)mm

QC-3690 $64.95

Mini Colour Pinhole CCD Camera

- Lens: 3.7mm
- Dimensions: 36(W) x 36(H) x 15.9(D)mm

QC-3692 $69.95

Mini Colour CCD Camera with IR

- Lens: 3.6mm
- Dimensions: 36(W) x 36(H) x 15.9(D)mm

QC-3694 $69.95

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Refer: Silicon Chip Magazine June, 2011

Control the speed of 12 or 24VDC motors from zero to full power, up to 20A. Features optional soft start, adjustable pulse frequency to reduce motor noise, and low battery protection. The speed is set using the onboard trimpot, or by using an external potentiometer (available separately, use RP-3510).

NEW 2011

$39.95

- Kit supplied with silk-screened PCB and all onboard electronic components.
- Suitable enclosure UB3 case, HB-6013 sold separately

KC-5502

KIT OF THE MONTH

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Combining the functions of a pure sine wave inverter, battery charger and automatic transfer switch in one unit, these are the ideal power solution for mobile and recreational vehicle applications. When connected to the mains, the load is taken from the mains and the connected batteries are charged. If the mains is interrupted or exceeds the allowable limits, power is drawn from the batteries and mains power is provided by the inverter. This ensures a seamless supply of power in your caravan, 4WD or recreational vehicle - plug into mains power when it's available, and automatically flick over to battery power when mains is removed. No more manual switching from mains to battery power!

FROM **$1499.00**

- Battery voltage: 12VDC
- Battery charge current: 20A

1500W Sine Wave Inverter/Charger

- Weight: 5.2kg
- Dimensions: 520(L) x 200(W) x 88(H)mm

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- Weight: 6.4kg
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NEW 2011

STIRLING ENGINE PROJECT KIT

A Stirling engine is a machine that converts heat into mechanical energy. The expanding air acts on a piston to provide mechanical force: simply heat up the air chamber, give the flywheel a whirl and away it goes.

Made in Germany, our Stirling engine is beautifully engineered from stainless steel, brass and a genuine beech base. It has 2 ball bearings and should become an heirloom, THIS IS A KIT, ASSEMBLY REQUIRED!

$249.00

- Recommended for ages 12+
- Adult supervision recommended
- Dimensions:156(L) x 108(W) x 70(H)mm

YM-2923

5.8GHZ AV SENDER EXPERIMENTERS KIT WITH IR RECEIVERS

All AV sender transmitters are limited to strict controls and output power. This unit is for qualified and licensed amateur radio experimenters only as it has ten times the output power of standard units (100mW). In keeping with the experimental nature of the unit, it is not ready to plug in. Several parts such as the supplied RCA sockets need to be soldered in. It also doesn't come with a set of cases. It uses a standard 9V adaptor that comes with the unit. The extra power works well with experiments in, say concrete buildings with lots of reinforcing steel. In all respects except output power, it's identical to AR-1840 AV sender

NEW 2011

- Video input: Composite for NTSC or PAL
- IR frequency: 433.92MHz
- IR modulation: ASK
- IR carrier: 30 - 60kHz
- Range: Up to 300m (line of sight)
- Operating frequency: 5.76 - 5.86GHz (6 channels)
- Transmission power: 20 dBm (100mW)
- Receiver sensitivity: -85dBm
- Operating voltage: 9VDC
- Power consumption: TX: max. 500mA @9V RX: max. 400mA @9V
- Dimensions: TX/RX PCB: 111(L) x 62(W)mm

$249.00

AR-1840

Caution: This product requires further assembly, which assumes technical competence. If you feel that this may be above your skill level, please return the unit in its original packaging, with receipt, under our standard satisfaction guarantee terms. Once construction or soldering has begun we will not accept the unit back under any circumstances.

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An ideal entry-level soldering station for the hobby user. Comes with a lightweight iron with anti-slip grip and tip cleaning sponge, with temperature adjustment from 150-450°C.

- Dimensions: 135(L) x 82(W) x 70(H)mm

TS-1620

$59.95

60W Soldering Iron - 12VDC

A quality 12V soldering iron. Plugs into your car cigarette lighter and with 60 watt, it's hot enough to solder terminals, heavy cable etc.

- 2.5 metre lead length
- Supplied with a length of solder as well.

$17.95

Note: Before use, check your car's wiring is enough to carry the current, or else connect direct to the battery.

TS-1530

Portasol Super Pro Gas Soldering Tool Kit

Features 90 minute run time, 10 second fill, maximum 1300°C temperature and 40 second heat up. The kit contains a Portasol Super Pro Gas Soldering Iron, and all of the following:

FREE Butane Gas (NA-1020) with every purchase valued at $5.95

- Quality storage case, cleaning sponge and tray, 2.4mm & 4.8mm double flat tips, hot air blow, hot knife tip, hot air deflector

TS-1328

$159.00

6W Soldering Iron - Battery Powered

Battery powered soldering irons have come a long way. This 6W model will re-solder a dry joint or fix a solder lug, etc. It is ideal in potentially explosive situations, such as bilge, or where petrol fumes may be present. Reaches full temp in about 10 seconds.

- Uses 3 x AA batteries (not included)
- Size: 175(L) x 36(W) x 18(D)mm

TS-1535

$19.95

FREE Batteries (SB-2425) with every purchase valued at $3.95

STAINLESS STEEL TWEEZER SET - ESD SAFE

NEW 2012

Set of 3 tweezers, duckbill head, angle fine and straight superfine enable you to manipulate surface mount components or other tiny items with ease. ESD coating on main body of tweezers reduces static discharge issues.

- Measures: Angled & duckbill 120mm, superfine 135mm

HT-1760

$19.95

GLUE LINED PRE-CUT HEATSHRINK TUBING - TRADE PACK

Glue lined heatshrink in an array of sizes to suit all needs - 60 pieces in total. Supplied in see through nylon snap shut case.

- 95mm long
- Box measures: 205(W) x 108(D) x 35(H)mm

WH-5521

$29.95

BUDGET DIGITAL VERNIER CALIPER

The digital display is calibrated in imperial and metric units with a corresponding scale etched onto the caliper slide. Perfectly suited to the home handyperson and is the ideal caliper for woodworkers.

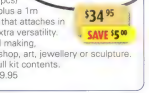
- 150mm measurement range
- 245mm length (closed)
- Internal and external jaws
- 0.1mm resolution

TD-2081

$19.95

ROTARY TOOL KIT WITH FLEXIBLE SHAFT

The kit consists of a powerful 32,000 RPM rotary tool that you can use with numerous attachments (210 pcs), in the usual way, plus a 1m long flexible shaft that attaches in seconds to give extra versatility. Suitable for model making, automotive, workshop, art, jewellery or sculpture. See website for full kit contents.



TD-2459 WAS $39.95

$34.95 SAVE $5.00

CABLE TIE BOX - 400 PIECES

Box of 400 black cable ties in various sizes: 200mm, 150mm & 100mm. Supplied in a re-usable box with compartment storage.

- UV stability
- Box measures: 260(W) x 180(D) x 40(H)mm

HP-1216

$19.95

Also available:

Releasable Cable 30 Tie Pack

HP-1217 $6.95

NEW 2012

GAMING CONSOLE TOOL KIT

Everything you need to get into your gaming console and accessories. Includes tools for pretty much every console and handheld on the market today - WII®, X-Box®, Playstation® etc. Carry case included. See website for full list contents.

TD-2109 WAS $29.95

$24.95 SAVE $5.00

Also available:

Computer Tool Kit

TD-2150 WAS $19.95 **NOW $14.95** SAVE $5.00

PENCIL BUTANE TORCH

Pocket sized gas torch for heatshrinking, soldering etc and uses standard butane gas. Adjustable flame, all metal construction.

- Size: 205(L) x 13(D)almm

TS-1667

$11.95

MINI GLUE GUN - 240V

A handy tool to have around the house. It's fast, easy and simple to use with trigger controlled glue feed. Plugs straight into 240V power point. Perfect fix for toys, decorations, furniture, woodwork, cardboard etc.

- Standards Australia approved
- Requires glue sticks with 7.4mm diameter

TH-1990

$19.95

FREE Glue Stick 6pk (TH-1991) with every purchase valued at $3.95

Note: Intermittent use only, not for production use.

PROJECTS MADE EASY

PCB Holder with Magnifying Glass

An extra pair of hands and eyes for those fiddly jobs. Supports PCBs while soldering etc. Great for model builders and other hobbyists.

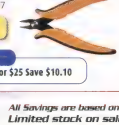
- 145mm high

TH-1983

$12.95

Precision 5" Angled Side Cutters

Ideal for fine PCB work. They will easily cut leads flush with the board's surface. Made from quality carbon steel and have soft padded handles.



TH-1897

$11.95

DEAL

Buy all 4 for $25 Save $10.10

Solder Sucker & Blower Bulb

A quick & simple bulb type solder sucker that is affordable, compact and effective. Buy two or three and you will always have one handy.

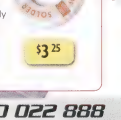
- Size: Approx. 50(D) x 110(L)mm

TH-1850

$6.95

3mm De-Solder Braid

A specially treated piece of braid for removing solder from a PCB. Place the braid over the solder and apply soldering iron to efficiently remove solder.



- 3mm wide, 120mm long

NS-3020

$3.25

DIGITAL MULTIMETERS

Cat II Autoranging DMM

Suitable for voltages up to 600VAC and has 15mm high digits for easy reference. Features include overload protection, 10A AC & DC current, diode check, data hold & backlit display.

- Display: 2000 count
- Category: Cat II 600V

QM-1524

$19.95

Compact Cat III Multimeter with Temperature

A budget-priced meter with everything you need - capacitance, temperature and 10A on AC and DC, compact and light weight with rugged double moulded housing.

- Display: 4000 count
- Cat III 600V
- Duty cycle, backlit
- Non-contact voltage
- Dimensions: 137(H) x 66(W) x 35(D)mm

QM-1323

$39.95

True RMS Autoranging DMM

Features large 20mm high digits, True RMS measurement, temperature, capacitance, relative measurement, data hold, temperature and more. Includes holster and temperature probe.

- Display: 4000 count
- Category: Cat III 600V
- Dimensions: 196(H) x 96(W) x 51(D)mm

QM-1536 WAS $79.95

$59.95
SAVE $20.00

VACUUM BENCH VICE WITH 75MM JAW

A robust bench vice with a powerful suction base. The vice consists of three-pieces; a vacuum base, ball joint clamp and a 75mm opening jaw with removable soft rubber jaw covers. The jaws have 'V' grooves for holding cylindrical or irregular shapes making it well suited to small bench jobs.

- Stands approximately 160mm tall

TH-1766

$29.95

ILLUMINATED GOOSENECK MAGNIFIER

This handy hobbyist's magnifier has a 2x main magnifier lens with 5x insert lens and 2 LED lights, all mounted on a flexible arm. Can be free-standing or clamped to a surface up to 38mm thick. Lens comes with a soft protective pouch.

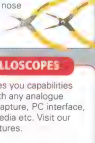
- Lens: 110(dia)mm
- Stands: 225mm high
- Requires 3 x AAA batteries (SB-2413)

QM-3532 WAS $29.95

$24.95
SAVE $5.00

STAINLESS CUTTER / PLIERS SET

Set of five 115mm cutters and pliers for electronics, hobbies, beading or other crafts. Stainless steel with soft ergonomic grips.



- Contains: flush cutters, long nose pliers, flat nose pliers, bent nose pliers, round nose pliers

TH-1812

$29.95

IDC CRIMPING TOOL

Suits all IDC cable connectors. Commonly used for connecting items such as SCSI and IDE computer plugs. Don't destroy connectors with a vice or a hammer, crimp them the easy way.

- Crimping distance from 27.5mm to 6mm (with attachment).

TH-1941 WAS $14.95

$11.95
SAVE $3.00

7 PIECE CR-V SCREWDRIVER SET

Made to last from an alloy of heat-treated chrome vanadium and molybdenum steel for high wear resistance and strength. The set contains:

- Slotted: 2.5 x 75, 5 x 75, 5 x 150, 6 x 125mm
- Phillips: #0 x 75, #1 x 75, #2 x 100mm

TD-2088

NEW 2013

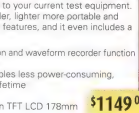
$9.95

DIGITAL STORAGE OSCILLOSCOPES

The advantages of a DSO gives you capabilities that simply aren't possible with any analogue oscilloscope, including trace capture, PC interface, storage of data on portable media etc. Visit our website for more detailed features.

25MHz Dual Trace DSO

Ideal entry-level DSO for the advanced hobby user or technician and is particularly suited to audio work. Full data storage capabilities and USB interface so you can store traces on a flash drive.



- Channels: 2
- Display: Colour TFT LCD 145mm
- Weight: 2.4kg
- Dimensions: 310(W) x 150(H) x 130(D)mm

QC-1932

$599.00

7" Screen 100MHz Dual Channel DSO

Enhanced performance, professional level test instrument for the technician, design engineer or development laboratory. Full 100MHz bandwidth to keep up with the current digital chip technology, plus a host of features that make it a cost-effective addition or upgrade to your current test equipment. Big 7" screen, smaller, lighter more portable and with a host of extra features, and it even includes a carry bag.

- Digital filter function and waveform recorder function
- Pass/fail function
- Screen-saver enables less power-consuming, prolong product lifetime
- Channels: 2
- Display: Colour 7in TFT LCD 178mm
- Weight: 2.4kg
- Dimensions: 340(W) x 150(H) x 110(D)mm

QC-1934

$1149.00

Both models include probes, Easyscope software & a USB cable

15 PIECE MICRO DRIVER SET

This handy set will fit the bill for all those microscopic fasteners we come across in modern electronics.

- Contains: Slotted: 1, 1.4, 1.8, & 2.4mm, Phillips: #000, #00, #0, #1, Torx: T5, T6,T7, & T8, Hex: 1.5, 2, & 2.5mm
- Drivers: 105mm long
- Case size: 192(L) x 130(W) x 26(H)mm

TD-2069 WAS $24.95

$19.95
SAVE $5.00

100 PIECE DRIVER BIT SET

This is an excellent driver bit set that contains just about every bit you could ever use. It has a magnetic holder, adaptors, Phillips bits, slotted bits, torx, tamperproof, pin drive, and even a wing nut driver - Fantastic. See web site for full listing

TD-2038

$19.95

EASY DISTANCE MEASURING

Ultrasonic Distance Meter with Laser

Measure distance quickly from a remote position. This ultrasonic measurer calculates area, sums total readings and stores data for later use in imperial or metric units. Laser pointer for accurate placement of the measurement point. Requires flat unobstructed surface to measure againts.

- Backlit LCD
- Auto or manual power-off
- Dimensions: 175(L) x 62(W) x 45(D)mm

QP-2295 WAS $44.95

Case & Belt Clip included

$34.95
SAVE $10.00

Professional Laser Distance Meter

This comprehensive measurement tool adds, subtracts and calculates area, volume and takes indirect measurements. The memory stores up to 20 historical records and these can be used for area and volume calculations. Invaluable for architects, estimators, builders or renovators.

SAVE $$$

- Area and volume calculations
- Add/subtract measurements
- Continuous measurement
- Min/max distance tracking
- Backlit LCD
- Laser accuracy
- Dimensions: 110(L) x 47(W) x 28(H)mm

QM-1621 WAS $199.00

$179.00
SAVE $20.00

Battery & Case included

Limited stock on sale items.
All Savings are based on Original RRP

Power Management Systems

SUPER COMBI POWER MANAGEMENT SYSTEM

These Rich Electric SuperCombi inverter/chargers are the ultimate solution to your power management needs for a wide range of applications. From caravans and motorhomes, to marine and household remote power systems, the SuperCombi is up to the task of supplying and managing your power needs whatever your application. Featuring super-rugged design and build quality to withstand harsh Australian conditions, these units are capable of delivering their FULL rated power output all the way up to an impressive 70°C operating temperature. See website for more information.

- True pure sinewave interactive inverter/charger
- Auto-transfer switch (ATS)
- Dynamic Power Shifting
- Power support
- DC generator input up tp 700 amps
- Solar panel controller input up to 600 amps
- Programmable DC control switches
- Stackable
- Interactive power sharing
- Multi-phase supply
- Green Power Smart feature

SAVE $$$

		Was	Now	Save
12V 1500W	MI-5250	$3199.00	$2999.00	$200.00
24V 1500W	MI-5251	$3199.00	$2999.00	$200.00
12V 3000W	MI-5252	$4399.00	$4199.00	$200.00
24V 3000W	MI-5253	$4399.00	$4199.00	$200.00

Also available:

CombiPlus Power Management Systems.

		Was	Now	Save
12V 1500W	MI-5270	$2899.00	$2699.00	$200.00
24V 1500W	MI-5273	$3799.00	$3599.00	$200.00

Sydney Grid-Tie Installation

2 year

MORE INFO AVAILABLE ONLINE

FROM $2999.00

Accessories to suit both SuperCombi and CombiPlus Units

Multiphase data hub	MI-5276	$199.00
Parallel stack data hub	MI-5277	$199.00
Battery temperature sensor	MI-5278	$69.00
Remote control for SuperCombi	MI-5269	$439.00
Remote control for CombiPlus	MI-5279	$379.00
Linkable Solar Charge Controller 45A	MP-3726	$389.00
Linkable Solar Charge Controller 60A	MP-3728	$459.00

Check our POWERSTACK HIGH PERFORMANCE BATTERY BANKS to suit these systems. See our friendly staff and or website.

REMOTE POWER PACKAGES

For those living in locations where mains electricity isn't available, or expensive to have connected, a remote power system is the best solution to household power needs. Whilst a remote power system can be a major investment, Jaycar offers packages to suit your needs and there are government incentives (Australia only) & rebates that may support your purchase*. Each packages contains the necessary number of solar panels, a fully featured inverter-charger power management system, solar charge controller, high capacity deep cycle battery banks, cables, connectors and cable-termination tooling. Just add the appropriate panel mounting hardware.

FROM $12,500.00

3kWh Per Day with 1kW Solar

Three days system autonomy at 3kWh per day usage: About 3.5kWh solar charging provided per day on average.
MP-9005 WAS $13,990.00
NOW $12,500.00 SAVE $1,490.00

5kWh Per Day with 1.575kW Solar

Four days system autonomy at 5kWh per day usage: About 5.2kWh solar charging provided per day on average.
MP-9007 WAS $22,990.00
NOW $19,990.00 SAVE $3,000.00

Also available: **10kWh Per Day with 3.15kW Solar** MP-9009 WAS $39,990.00
NOW $35,500.00 SAVE $4,490.00
*Must meet criteria for Solar Credits scheme. See www.orer.gov.au for details

Note: Due to size and weight of items in these packages, not all parts are available in-store. Please speak with our staff for more information.

SAVE $$$

BATTERY-TO-BATTERY DC CHARGE CONTROLLER 12 - 24V 140A

Fully programmable, battery-to-battery charge controller system with a variety of applications as a charge or load controller. It can be used as a bi-directional, fully programmable battery to battery charge controller. Alternatively, it can be used as an independent, fully programmable DC load controller low voltage disconnect / re-connect with programmable twin timer functions. Or finally, it can be used in conjunction with the SuperCombi power management system as the DC load controller or DC generator input. Suitable for 12V or 24V systems, up to 140A maximum current.

- Operating voltage: 9-35VDC
- Over-voltage protection
- Dimensions: 111(W) x 90(H) x 58(D)mm

MI-5282

MORE INFO AVAILABLE ONLINE

$279.00

12V 150AH AGM DEEP CYCLE BATTERY

Designed to perform in harsh tropical conditions, and with a superior high rate discharge performance and higher cycle service life, this battery is perfect for a wide array of applications including remote solar systems, 4WD, caravan and RV, motorhome, and marine.
See our website for a full specification datasheet.

$699.00

- Small footprint to suit installations in tight areas
- Advanced AGM (absorbed glass matt) technology
- Cycle life: 1800+ @ 20% DOD, 500+ @ 80% DOD
- Voltage: 12VDC
- Capacity: 150Ah (10hr rate), 164Ah (20hr rate)
- Weight: 52kg
- Dimensions: 123(W) x 556(D) x 296(H)mm

SB-1822

Note: Not stocked in all stores but can be ordered. Call your nearest store for details.

POWERTECH MONOCRYSTALLINE SOLAR PANELS

As strong and tough as the better known brands, but at a more attractive price.

- Sizes range from 5 watts to a massive 175 watts
- For full technical spec ask in-store or visit online
- QC tested - all come with test certificate
- 20 year limited warranty

FROM $32.95

SAVE $$$

Get 10% off all our solar mounting brackets with every panel purchased

			Was	Now	Save
12V	**5 Watt**	ZM-9091	$39.95	$32.95	**$7.00**
12V	**10 Watt**	ZM-9093	$64.95	$59.95	**$5.00**
12V	**20 Watt**	ZM-9094	$119.00	$115.00	**$4.00**
12V	**40 Watt**	ZM-9095	$225.00	$219.00	**$6.00**
12V	**65 Watt**	ZM-9096	$359.00	$349.00	**$10.00**
12V	**80 Watt**	ZM-9097	$429.00	$399.00	**$30.00**
12V	**120 Watt**	ZM-9098	$639.00	$579.00	**$60.00**
24V	**175 Watt**	ZM-9099	$899.00	$849.00	**$50.00**

MONITOR YOUR POWER BILL THIS WINTER

Deluxe Mains Power Meter with CO_2 Measurement

Save power costs by monitoring what your appliances use. This meter tells you the cost of electricity consumption of an appliance plugged into it and the amount of power used in kilowatt hours, as well as how many cumulative kg of CO_2 the appliance is putting into the atmosphere.

- Extra large LCD for easy reading
- Dimensions: 120(L) x 58(W) x 40(H)mm

MS-6118

$29.95

Mains Standby Power Saver with IR Receiver

This energy saving device eliminates the standby power consumed by most modern appliances. Simply program the power saver with the standby level for your system and it will shut the power off whenever the set level is reached. Program any IR remote control to turn the power saver on again for simple and effective operation.

- Dimensions: 128(H) x 65(W) x 40(D)mm

MS-6146 WAS $39.95

$29.95

SAVE $10.00

Mains Wireless Power Monitor

Monitor your household's electricity consumption simply and easily. With the sensor unit installed in your fuse box, your household power usage data is wirelessly transmitted to the indoor display unit up to 50m away. You can also scrutinise your week-to-date and year-to-date energy consumption. The indoor LCD receiver unit runs on 2 x AA batteries (included).

- Electricity usage, cost and time displayed
- Suitable for single phase only
- Dimensions:
  Display unit: 101(H) x 80(W) x 42(D)mm
  Sensor unit: 75(L) x 60(W) x 35(H)mm

MS-6160

$99.95

4 X AA SOLAR BATTERY CHARGER

The solar panel in the lid will charge up to 4 x AA Ni-Cd or Ni-MH batteries in a fairly short time. Ideal for yachts, campers or anywhere 240V is not available.

- Size: 67(W) x 30(H)x 96(D)mm

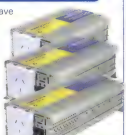
MB-3502
WAS $23.95

$14.95

SAVE $9.00

MODIFIED SINEWAVE INVERTERS

These modified sine wave inverters will produce mains power from a vehicle's battery. A 150W inverter will run some laptops, lights, small TVs & recharge batteries. Inverters 300W & above will also recharge power tools, run fluorescents & larger style TV's. Take your creature comforts with you when you go bush or on any road trip.



Great New Prices

150W	12VDC to 230VAC	MI-5102	$49.95
300W	12VDC to 230VAC	MI-5104	$69.95
400W	12VDC to 230VAC	MI-5106	$99.00
400W	24VDC to 230VAC	MI-5107	$99.00
600W	12VDC to 230VAC	MI-5108	$169.00
800W	12VDC to 230VAC	MI-5110	$199.00
1000W	12VDC to 230VAC	MI-5112	$299.00
1500W	12VDC to 230VAC	MI-5114	$449.00
2000W	24VDC to 230VAC	MI-5116	$549.00

Pure sinewave inverters also available. See in-store or on website

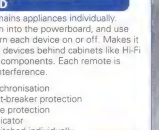
4 OUTLET REMOTE CONTROL POWERBOARD

Control up to 4 mains appliances individually. Simply plug them into the powerboard, and use the remote to turn each device on or off. Makes it easier to turn off devices behind cabinets like Hi-Fi or home theatre components. Each remote is coded to avoid interference.

- One-touch synchronisation
- Overload circuit-breaker protection
- Surge and spike protection
- LED power indicator
- Each outlet switched individually

MS-6150

$59.95



Note: This product is not suitable for use with inverters or UPS units.

150 LUMEN MAGNETIC TORCH WITH GOOSENECK

A tough & handy LED work light perfect for the home, in the car, garage and even in the office. Position light exactly where you need it with a flexible tube & powerful magnetic base, the high powered 3W LED will emit a very bright focused beam. Aluminium build, designed to last. Requires 3 x AA batteries.

- Output: 150 lumens
- Burn time: 15 hours
- Dimensions: 35(D) x 180(L)mm

ST-3460

$49.95

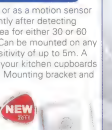
3 IN 1 MOTION SENSOR LIGHT

Use it as a torch, a spotlight or as a motion sensor light! It will switch on instantly after detecting motion and illuminate the area for either 30 or 60 seconds before it goes off. Can be mounted on any surface and has motion sensitivity of up to 5m. A great idea for areas such as your kitchen cupboards or pantry, sheds & hallways. Mounting bracket and hardware included.

- Eco-friendly - using LED & motion sensor
- Requires 2 x AA batteries (not included)
- Dimensions with bracket: 106(L) x 92(H) x 33(D)mm

ST-3203

$19.95



12VDC CCTV MAINS POWER SUPPLIES

Mains power supplies suitable for CCTV installations, with multi-channel outputs for each individual camera. Housed in a rugged lockable steel enclosure designed for permanent professional installations. Must be installed by a licensed Electrician.

4 x separate 12-14V DC channels
MP-3850 $69.95

9 x separate 12-14V DC channels
MP-3852 $129.00

Both units have:

- Each DC power channel has secure, screw down terminals with rear panel wiring access
- Mains hardwire connection via screw down terminals with safety cover
- Each 12VDC output channel is individually fused, and can be switched ON/OFF with jumpers
- Output voltage: adjustable from 11-13VDC
- Output current: MP-3850 3.0A total
  MP-3852 5.0A total
- AC input: 100-240V 50-60Hz
- LED power on status on locked panel face
- Dimensions: MP-3850 163(L) x 163(W) x 48(D)mm
  MP-3852 203(L) x 163(W) x 54(D)mm

WARNING:
Whilst these units have a secure plastic cover over the switchmode circuitry, mains wiring is still accessible. We strongly recommend that only licensed electricians are used to connect the unit to power mains.

FROM **$69.95**

MP-3850 shown

DUAL BATTERY ISOLATORS WITH ADJUSTABLE DISCONNECT/RECONNECT

This dual battery isolator, or voltage sensitive relay (VSR), is the link that allows both batteries to charge whilst your engine is running, but keeps your main engine cranking battery isolated from being discharged by your 12V accessories once camped. Cut-in and cut-out voltages are independently user adjustable, and it also features a manual override/jumpstart function. Two models available: MB-3680 for 12V batteries, and MB-3682 for 24V batteries.

- 100% solid state technology with extremely low standby current and voltage drop
- 10 user adjustable set points for disconnect and reconnect voltages
- Over current, over voltage and over temperature protection
- Emergency over-ride feature
- Can be used independently as a low voltage disconnect/reconnect for a 100A load
- Dimensions: 162(L) x 75(W) x 50(D)mm

$119.00 each

12V batteries MB-3680 $119.00
24V batteries MB-3682 $119.00

Note: 24V version not stocked in stores but can be ordered. Call your nearest store for details.

TWINKLE LASER LIGHT SHOWS

Produce spectacular lighting effects with hundreds of twinkling and constantly moving laser lights. Lightweight and compact, these laser projectors are suitable for portable lighting setups.

NEW 2013

Red & Green Mini Laser Show

NEW 2013

Basic economy model provides red & green twinkle laser light display. Sound activated, auto or remote control with variable modulation. Manually controlled only.

- Control mode: Sound active, auto, remote control
- Mains operated from 9-12VDC plugpack (included)
- Dimensions: 135(L) x 105(W) x 55(H)mm

SL-3439

$149.00

Red and Green Twinkle Laser Show with Blue Waterfall Feature

DMX control, red and green twinkle displays along with spectacular high power blue LED waterfall effect. Adjustable dimmer, rotation speed and stroboscopic function.

- Key protection safety function
- Brightness adjustment
- Scattering function
- Mains powered
- Dimensions: 200(L) x 85(W) x 158(H)mm

SL-3437

$299.00

ANIMATION GREEN LASER SHOW WITH ILDA

NEW 2013

ILDA (International Laser Display Association) capability enables full software integration and complex animation of your laser show. The unit comes with pre-programmed displays and characters, but with the use of ILDA software such as Zion®, Millennium® or V3D® you can add PC control to create cartoon, letters, figures or other characters. Software is not included.

- ILDA software or DMX control
- Control mode: Sound active, automatic, DMX (6 channels), master/slave
- Mains powered
- Dimensions: 270(L) x 80(W) x 174(H)mm

SL-3438

$399.00

GREEN LASER STAR PROJECTOR

This unit projects thousands of dazzling green laser star like formations to your ceiling. Comes with an integrated amplified speaker to connect your iPod® and MP3s to blast your tunes through the stars.

- Colour changing LEDs
- 6W motion light
- Dimensions: 140(L) x 140(H) x 110(D)mm

SL-2931 WAS $119.00

$99.00
SAVE $20.00

ACTIVE PA SPEAKERS WITH MP3 CONTROLLER

2- way active PA speakers that are not only powerful but also extremely portable. Incorporates a 12" or 15" woofer and compression driver, 3 channels with balanced XLR inputs and 1/4" unbalanced inputs, RCA line level inputs and an MP3 controller. Ideal for DJ, PA for schools, sports, churches, weddings, conferences etc.

- SD card and USB inputs
- Titanium tweeter
- 2 band equaliser

12" Active PA Speaker with MP3 Controller

SAVE $$$

- 200WRMS power output
- Weight: 20kg
- Dimensions: 620(H) x 400(W) x 400(D)mm

CS-2529 $399.00

FROM $399.00

DEAL

Buy 2 for $699 SAVE $99

15" Active PA Speaker with MP3 Controller

- 300WRMS power output
- Weight: 28kg
- Dimensions: 690(H) x 460(W) x 400(D)mm

CS-2530 $469.00

DEAL

Buy 2 for $799 SAVE $139

PARTY LIGHTING

LED Linkable Party Lights with Controller

Turn a lifeless party into an exciting one with these linkable blue, amber and red LED party lights. They have a built-in sound modulator that allows for the lights to switch in time with the beat. Microphone sensitivity and light chaser speed functions are fully adjustable. Units are mains powered, easy to operate and designed to last. Two models available:

NEW 2013

3 LED Linkable Party Light

- Dimensions: 14(L) x 13(W) x 48(H)mm

SL-2911 $49.95

6 LED Linkable Party Light

- Dimensions: 35(L) x 13(W) x 36(H)mm

SL-2913 $79.95

FROM $49.95

Rotating Disco Ball with LED Spotlights

NEW 2013

This brilliant mirror ball and LED spotlights station features an automatic rotating mirror ball, two adjustable angle spotlights with 8 LEDs in each which alternate between red, green and blue. It also has an additional 4 LEDs on the base for maximum effect. Mains power adaptor included.

- Dimensions: 260(L) x 130(W) x 230(H)mm

SL-2916

$39.95

BUILD-IT YOURSELF

DMX Controller USB Interface Kit

Add computer control to your DJ or stage show. This kit controls DMX fixtures such as spotlights using a PC and USB interface. Includes software, USB cable and enclosure. DLL is provided so you can write your own software if you like. It can also be operated in stand-alone mode that outputs all 512 channels at the same time (9V battery required for stand-alone mode).

- 512 DMX channels with 256 levels each
- 3 pin XLR-DMX output connector
- Windows 98SE or higher compatible
- Dimensions: 106(L) x 100(W) x 44(H)mm

KV-3610

$149.00

DMX Relay Control Kit

Control a relay with the DMX512 protocol. It is actually a bus-controlled power driver. The relay will be activated when the DMX value of the set channel equals 140 or more and turns off when the value is 120 or less. Short form kit contains DMX-512, XLR plug, PCB and all specified components.

- 512 unique addresses, DIP switch settable
- LED indication for power supply, relay output and error status
- Relay hold function in case of DMX signal loss

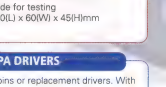
KV-3612

$49.95

DMX Control Dimmer Kit

Allows you to control a lamp or group of lamps through a DMX signal. Use the USB Controlled DMX Interface kit or any other control console compliant with the DMX-512 protocol as a controller. It will drive resistive loads like incandescent lamps and mains voltage halogen lighting. Short form kit.

$79.95



- 512 unique addresses, selectable with DIP switch
- Status LED for power and error detection
- Stand alone mode for testing
- Dimensions: 150(L) x 60(W) x 45(H)mm

KV-3614

PAPER CONE PA DRIVERS

Ideal for DIY PA bins or replacement drivers. With aluminium frames, high efficiency and power handling capacity, these drivers offer exceptional value. Full specifications on website.

10" Paper Cone PA Driver

- Power handling: 150WRMS

CG-2381 WAS $99.00
NOW $89.00
SAVE $10.00

12" Paper Cone PA Driver

- Power handling: 200WRMS

CG-2383 WAS $119.00
NOW $99.00 SAVE $20.00

SAVE $$$

FROM $89.00

NOTEBOOK ACCESSORIES

Portable Study Table with Notebook Cooler

Lots of applications for this handy fold-up table. Features two work surfaces - the adjustable sloping and the flat surface. The legs are height-adjustable, has a pen and cup holder and cooling fans for your laptop. The whole lot folds up neatly for easy transport and storage.

- Retractable USB cable included
- Size folded: 285(W) x 316(H) x 36(D)mm
- Size unfolded: 570(W) x 316(H) x 36(D)mm

XC-5218

Note: Laptop not included

$29.95

NEW SIZE

Combination Notebook Cable Lock

This laptop security cable has a four digit combination that you can customise for security. It's 1.8m long and has a swivel on the end so moving it around your desk area will not be a problem.

- Steel lock mechanism

XC-4639 WAS $17.95

$12.95 SAVE $5.00

Tiny 300k Notebook USB Webcam

Excellent for on-the-go online video conferencing or chatting. It has a built-in microphone to keep your setup as minimalist as possible. Comfortably mounts on top of a thin LCD laptop screen.

- Driverless, plug and play
- 300k resolution
- Dimensions: 28(W) x 59(H x 14(D)mm

QC-3231

$19.95

USB Powered Notebook Light

Use this USB port powered light when looking inside a computer, or when on the road with a laptop. Twist the head to turn On/ Off, and it has a gooseneck for universal angle adjustment.

ST-2808

$14.95

DEAL

Buy 2 for $20 SAVE $9.90

USB 3.0

ExpressCard with 2 x USB3.0 Ports

Achieve transfer speeds of up to 2.5Gbps with this ExpressCard to 2 x USB 3.0 port adaptor for your laptop. Though unable to reach the maximum theoretical speed of USB 3.0 due to ExpressCard bandwidth limitations it is still more than triple the speed of USB2.0 (480Mbps). This is more than enough for a significant reduction in transfer times.

- Compatible with XP, Vista and 7 (32-bit and 64-bit)
- Compliant with ExpressCard standard release 0.95
- Dimensions: 95(L) x 68(H) x 14(D)mm

XC-4141 WAS $59.95

$49.95 SAVE $10.00

Add USB 3.0 to your Laptop

4-Port Powered USB 3.0 Hub

If you've made the upgrade to USB 3.0, you'll need a hub to run all your new peripherals. This one has four ports and provides a 4.8Gbps data rate, and significantly faster than USB 2.0.

- USB 3.0 lead and mains plugpack included
- Windows XP, Vista and 7
- Dimensions: 85(L) x 32(W) x 18(H)mm

XC-4947 WAS $69.95

$59.95 SAVE $10.00

MULTINETWORK CABLE TESTER WITH PIN OUT INDICATOR

Designed to quickly test UTP/STP/Coaxial/Modular network cables by manually or automatically scanning the wires for continuity, incorrect wiring and polarisation. It will sequence each connection and indicate the connections via two 9-way LED bar graphs. Main unit supplied with: Active RJ-45 terminator, 2 x RJ-45 to BNC adaptors and instruction manual.

- Requires 1 x 9V battery
- Dimensions: Main Unit: 104(L) x 62(W) x 26(D)mm Active Terminator: 100(L) x 30(W) x 25(D)mm

Note: Not suitable for Live circuits

XC-5076

FREE 9V battery ($8.2423) with every purchase valued at $3.95

$39.95

MINI SPEAKER

It's a rechargeable active speaker that can take a MicroSD card full of music files and it will play them in order or you can pause, play or skip to another track. It can be used as a laptop or computer speaker or plugged into a range of other devices such as iPods®, iPads® or any device that has an earphone jack. It also has an internal battery for charging via USB.

- Dimensions: 74(L) x 50(W) x 52(H)mm

XC-5176

NEW SIZE

$39.95

HIGH DEFINITION MEDIA PLAYERS

Once the media player is connected to your TV just attach your USB hard drive or thumb drive with your movies or SD card from your digital camera and start watching. Two models available:

720p Media Player with USB & SD Ports

- Supports AVI/MP4, DivX, Xvid, MPEG 1&2, RM, RMVB, DAT, MOV (not H.264) and VOB
- Maximum resolution: HDMI/YPbPr up to 720p

XC-4206 $89.00

1080p High Definition Media Player with USB, SD & LAN Ports

Ideal for movie marathons on cold winter nights

- Supported video formats: RM/RMVB/AVI/MPEG4 /MKV/M2TS/DivX/Xvid/Dat /VOB/MP4/MOV/SWF
- HDMI, YPbPr (YUV component) & AV outputs
- Ethernet connectivity (UPnP)

XC-4204 $139.00

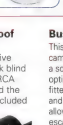
FROM $89.00

COMFORTABLE COMPUTER HEADPHONE & MICROPHONE

Extremely soft ear pads with a fabric headband beneath the stainless band, which evenly distribute the weight of the headset on your head to ensure comfort. The microphone is an electret condenser type on a sturdy but flexible metal gooseneck.

- Headphone transducers 40mm dia.
- Cable: 2.5m long with 2 x 3.5 stereo plugs for headphones and mic connection
- In-line volume control

AA-2078



NEW SIZE

$19.95

AUTO REVERSING CAMERAS

Rear View Mirror TFT Monitor with Camera

A complete rear-view safety package including a 7" TFT LCD monitor and a flush mount weatherproof camera. The monitor fits securely over your existing rear view mirror and can be quickly removed when needed. It has adjustable spring-loaded brackets to fit different sized mirrors and includes a slimline remote control. Additional camera (QC-3513) can be connected.

- 7 inch screen
- 5m video/power cable included
- Power: 12VDC
- Dimensions: 260(L) x 108(H) x 50(D)mm

QM-3762 WAS $249.00

Note: Should not be used as a substitute for a conventional rearview mirror unless the normal view is blocked.

$179.00 SAVE $70.00

Flush Mount Mini Waterproof Camera for Cars or Trucks

Designed for use in vehicles to give drivers a clear view of car or truck blind spots. A lengthy 5m composite RCA cable, a 730mm power cable, and the appropriate sized hole saw are included making this colour CMOS camera easy to install.

- 420TV Lines
- Power: 12VDC
- Dimensions: 31(L) x 20(Dia)mm

QC-3513

$89.95

DEAL

Buy QM-3762 & get the extra camera (QC-3513) for $69.95 SAVE $20

Bus / Truck Camera with Infrared LEDs

This tough unit can be firmly mounted inside as a surveillance camera or outside as a reversing camera. The camera is fitted to a solid bracket that can be rotated in a vertical motion for the optimal view. An RCA composite video and audio connection are fitted for compatibility with most in dash and security LCDs. Infrared LEDs will allow night vision so nothing will escape the cameras view.

- Power supply: 12VDC
- IP Rating: IP67
- Lens angle: 120
- Dimensions (including bracket): 73(L) x 45(W) x 53(H)mm

QC-3519 WAS $149.00

SAVE $55

$119.00 SAVE $30.00

Kits

ARDUINO DEVELOPMENT KITS

Arduino is an open-source electronics prototyping platform based on flexible, easy-to-use hardware and software. It can be used to develop interactive objects, taking inputs from a variety of switches or sensors, and controlling a variety of lights, motors, and other physical outputs (includes Jaycar stepper motors). Arduino projects can be stand-alone, or they can be communicate with software running on your computer. These Arduino development kits are 100% Arduino compatible.

EtherTen (100% Arduino Compatible with Onboard Ethernet)

100% Arduino compatible board that can talk to the world. Do Twitter updates automatically, serve web pages, connect to web services, display sensor data online, and control devices using a web browser. Any project you would previously have built with an Arduino and an Ethernet shield stacked together, you can now do all in a single, integrated board. See website for more details.

- Gold-plated PCB
- Top and bottom parts overlay
- Top-spec ATmega328P MCU
- Rounded corners

XC-4216

NEW 2011

$69.95

Eleven (100% Arduino Uno Compatible)

A copy of the exact Arduino Duemilanove board. It contains the ATmega328 microprocessor with a boot loader program so that you can communicate with it at switch-on. It has the standard I/O and is 100% compatible with the original Arduino concept. It contains some documentation and assembly instructions. See website for more information.

XC-4210

$39.95

ProtoShield Basic for Arduino

Fits directly onto an Arduino or Freeduino compatible board such as the Eleven and EtherTen so you can make more durable and permanent projects. The PCB is gold plated for durability, yellow solder masked, and features top and bottom overlay which clearly marks the GND and 5V rails. There is also mounting pads for a reset button, power on LED and current limiting resistor, and power supply capacitors.

- Size 59(L) x 53(W)mm

XC-4214

$4.45

Getting Started with Arduino

Arduino is an open-source development platform that enables experimenters to configure an open hardware design for a sirgle board microcontroller. This book explains what it is and how it works, and what you can do with it. It also includes a project to build complete with how to write the code to make it work.

- Softcover, 118 pages. 216 x 140mm

BM-7130

$23.95

Practical Arduino

A much larger and detailed book. It takes you beyond basics quite quickly and shows you how to make up a typical application / design. This is a necessity as it goes to the heart of Arduino.

- Softcover, 422 pages. 235 x 190mm

BM-7132

$57.95

NEWS & EVENTS

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KITS - BUILD THEM!

Headlight Reminder For Cars

Refer: Silicon Chip August 2001

Nothing is more frustrating than getting into your car early in the morning, only to discover that you had left your headlights on the night before, running your car's battery flat. Features include a modulated alarm, ignition and lights monitoring, optional door switch detection, time-out alarm and a short delay before the alarm sounds. Build and install this hassle-saving kit and enjoy a feature in your car that many luxury vehicle owners have long taken for granted. Kit includes quality solder masked PCB with overlay, case with screen printed lid and all electronic components. 12VDC.

- PCB: 78 x 49 mm

KC-5317

Don't get caught in the cold!

$27.95

Digital Multimeter Kit

Learn everything there is to know about component recognition and basic electronics with this comprehensive kit. From test leads to solder, everything you need for the construction of this meter is included. All you'll need is a soldering iron. Excellent choice for first year trade apprentices.

- Kit includes DMM case, LCD, solder, battery, test leads, PCB, manual and electronic components.
- Meter dimensions: 67(W) x 123(H) x 25(D)mm

KG-9250

$24.95

DAB+/FM Digital Radio Kit

There are very few digital radios available as Hi-Fi components and the few that are cost north of $700. Many Hi-Fi enthusiasts want to add a digital tuner to their system and want function and sound quality over bells and whistles. This kit covers DAB+ and FM, has analogue and optical audio outputs, IR remote (included), an external antenna connector and is powered by a mains plugpack. The kit is complete with everything, including the case. See website for full specs.

$399.00

- Digital station info display
- RCA and optical audio output
- External antenna connection
- Station memory presets
- 9VAC plugpack included

KC-5491

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NZ Freecall Orders Ph 0800 452 922

Arrival dates of new products in this flyer were confirmed at the time of print. Occasionally these dates change unexpectedly. Please ring your local store to check stock details. Prices valid from 24th June to 23rd July 2011. All savings are based on original RRP

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SERVICEMAN'S LOG

Restarting after the earthquake

Restarting a business after an earthquake isn't easy, especially when the workshop and its equipment is damaged and there's so much mess to clean up. However, I wasn't about to sit around and have all my previous efforts go down the drain.

Items Covered This Month

- Restarting after the earthquake
- Do-it-yourself starter motor repair
- Optical drive fun
- LG RT-42PX1 106cm plasma TV set
- HP/Agilent 3458A multimeter

After re-reading my article on the Christchurch earthquake in the May 2011 issue of SILICON CHIP, I realised that the story ended rather darkly. At that time, we did not know what would happen next and were not at all certain that our business would survive the quake. Since then, I'm happy to report some positive progress.

Small businesses like mine (and for many others in the service industry) rely on cash-flow to stay afloat. It is the air we breathe and no cash flow equals no business. Unlike big business, we don't have the resources to have accounts outstanding for months on end. That's because we have to pay our suppliers and other outgoings promptly, regardless as to whether we get money in or not.

In short, our suppliers rely on us paying them and we rely on customers paying us to keep the money-go-round going round.

After the quake, everyone was in shock and the city paralysed. After my initial inspection of the damage at my workshop, road closures meant that we could no longer even reach the building let alone get inside. When I closed the door on that day, the workshop was calf-deep in liquefaction and it was rising. In addition, large cracks through seemingly solid concrete floor slabs and wide-open "staircase" cracks up the concrete block walls meant the building might not be safe, so getting back in wasn't at the top of my to-do list.

WE RELY ON CASH FLOW TO STAY AFLOAT
~IT IS THE AIR WE BREATHE...

Because I thought that the workshop was ruined, the outlook appeared bleak. I had to keep reminding myself that people had died and that others had lost everything they owned under the rubble. We were alive with an intact house and contents and therefore were extremely fortunate.

Despite this, I was worried about my business and wondered how we could recover. There is nothing like a disaster to motivate people. Work crews toiling night and day soon had the roads and avenues cleared to at least one lane of traffic, while an army of students, farmers and other volunteers cleared thousands of tonnes of liquefaction and rubble from suburban footpaths and yards. Helicopter pilots donated flying hours and machines, while teams of chefs prepared donated food for free in order to fly hot meals in for the workers.

Similarly, rival power companies banded together and in just over a week had an overhead cable strung clear across town; a job that would normally take many months. And drain layers rapidly replaced shattered sewers with above-ground pipes in an effort to keep the waste moving.

Meanwhile, the government, in a rare show of actually doing something useful, offered wage subsidies to businesses unable to trade but having to pay staff. Although not normally being one to accept hand-outs, I nevertheless applied; we didn't know how long

...REMOVED THE OLD BRUSHES...

we'd be down and I wasn't about to forgo paying my employee. That relieved some of the financial pressure and although customers had already started leaving messages, we were initially in no position to help them.

Once the roads had been cleared, I was able to return to my workshop to further assess the damage. It's all very well sitting back and taking "free" money from the government but that's a short-term answer only. Our customers needed us and if we weren't there, they'd call someone else. I wasn't about to sit on my hands and watch all my hard-won clients go elsewhere, so I decided that we really had no choice but to get the business running again as soon as possible.

By now, I knew that the workshop wouldn't fall on me, so I decided to try to clean it up and at least start answering the phones and booking in jobs. By that time, most of our suppliers had re-opened and power, phones and the internet were all restored, so I had everything I needed to start trading.

I called my staff member and told him what I had in mind, assuring him we could get the building declared safe, though if he felt it too dangerous to work there, I would understand. He replied that he'd been thinking about it too and knew we had to get going or we'd likely not recover, so he would be there first thing in the morning.

His loyalty and can-do attitude confirmed I'd made the right choice in hiring him. With two of us pitching in, we would soon be on our way.

Unfortunately, every one of our specially-designed test rigs and workshop machines were still sitting where they fell and were thus water-damaged and useless. Our server was also dead and our workbenches literally shaken apart. Even the overhead fluorescent tubes had smashed together and disintegrated into a million bits, adding noxious powder and broken glass to the sticking foetid mess on the floors and workbenches.

Because we needed to conserve our available capital, we couldn't replace everything up-front, so we sat down and worked out what we'd need as a bare minimum. We then assembled what we could from our remaining stock and known good used parts, buying only when absolutely necessary. We built a new server and because one of the old server's RAID drives was still alive, it was up and running in no time.

Within two days, we had a bare-bones but functional workshop up and running.

The landlord would have to sort out the building. However, because he is elderly and lives in the country, he usually operates according to his own unique time, which us townies would call "dead slow". I impressed on him that unless the building was declared safe, we couldn't trade and if we couldn't trade, we couldn't pay rent.

To his credit he was there the next day with a building inspector/engineer who went through and declared everything safe. The landlord also brought in a crew to clean the outside of the place up so that we didn't have to tip-toe everywhere or wear gumboots to work.

The workshop still looks like a bomb has gone off in there but at least we are trading and slowly rebuilding. Earthquakes may break the hardest stone, but the human spirit is something altogether tougher.

Starter motor

A few years back, my dad, being the technical one in his family, was roped into doing some work on a relative's car. The car was having trouble starting and experience suggested that the starter motor was getting a bit tired.

In the grand old days, one simply removed the starter motor from the engine, unscrewed the brush covers, replaced the brushes, gave the commutator a bit of a rub with some wet and dry and buttoned it up. You then threw some fresh grease on the pinion and slapped it all back together for another 10 years of reliable service.

However, it wasn't quite so easy on my relative's car which was an expensive European model. This was at a time when the majority of cars on New Zealand roads tended to be an odd mixture of aging and fast-disappearing British marques and newer and much better equipped Japanese imports. In New Zealand, European cars have always tended to be relatively expensive to buy and maintain, with spares tending to be a bit on the pricey side. And even though the owner of this particular car was a man of some means, he baulked at paying the many hundreds of dollars they wanted for a new starter motor plus freight.

Throw in a 4-week wait for the part to arrive and it's easy to understand why he turned up at Dad's workshop, wanting to know if anything could be done to fix his present unit.

This particular starter motor, like a lot of European engineering, was a well-made unit. However, the rivets holding everything together, rather than the more usual screws, indicated that it was designed to be a throwaway item.

Dad quickly dealt with the rivets holding the end covers in place by drilling them out. Gently easing the covers away then revealed the armature, brushes and commutator end of the motor. And the problem was evident straight away – the brushes had worn all the way down to their copper braids.

Removing the old brushes simply involved lifting the springs and easing them out of their housings. To Dad's keen eye they looked like a standard-sized item and a quick trip to a local spare parts dealer and a few minutes spent comparing the old ones with several different brands soon produced a close match. While the new ones were a little longer than the originals, they fitted nicely into the brush-holders and a little extra initial spring tension

wouldn't hurt, even though it might increase the wear rate slightly.

The commutator was showing its age and was lightly scored, though it was considered not worth the hassle of splitting the case and removing the pinion gears just to give it a skim in the lathe. Dad made do with cleaning it up as best he could in-situ, then spent half an hour using a modified junior hacksaw blade to carefully under-cut the mica insulation sandwiched between the commutator segments. A few quick spins by hand with 100-grit wet and dry held to the commutator soon had everything looking good again.

After drilling the old rivet shafts from the body of the starter, dad replaced the covers and secured them in place with some small "PK-type" self-tapping screws. A quick test using a car battery showed it worked and so the starter was returned to its happy owner. It's still in the car and working many years later. The total cost of repairs, excluding labour, was $5.00 which was the cost of the brushes.

So if you have a sealed unit that's causing problems, you have nothing to lose by cracking it open and taking a look inside. You never know; it might be easy to fix and you could save yourself a small fortune over the cost of a new one.

Optical drive fun

It doesn't seem that long ago I paid $1000 for a 2-speed CD writer. While that seems a lot today, I have to admit that I made the money back (and then some) during the halcyon disk-burning days of the late nineties. Only "professionals" and hard-core hardware nuts bought such gadgets and once word got out that I had one, the orders came in thick and fast for back-up disks.

Of course, the boom didn't last long; a scant few years later, anyone could fit a burner into their computer for a song and back up their own disks, so that little cottage industry tanked relatively quickly – as did the PlayStation 1 chipping craze of around the same time. While I didn't chip any consoles, I knew of people making a lot of money doing nothing but.

For those unfamiliar with the scene, Sony all but tied up disk copy and zone protection with the PlayStation 1 by putting a boot sector at the start of every game disk. This wouldn't copy across to blank media in even the most comprehensive disk copy process, meaning that copied PlayStation games would not even load, let alone play, on unmodified consoles.

Then some bright spark came up with the idea of replacing the disk's boot sector with a hard-wired one soldered directly to the console's motherboard. This "fooled" the console into booting from that instead of the disk's boot sector (which of course didn't even exist in backed-up games) and so the chipping boom began. The Internet made it a global phenomenon and some technicians were installing chips into consoles as fast as they could program them.

Of course, this modification voided any warranties and there was always the possibility that a console wouldn't work at all after one of the dodgier "chippers" had had a crack at it. Being a computer gamer rather than a console gamer, the whole chipping thing didn't affect me and while I didn't agree with the rampant pirating of games this craze appeared to encourage, I did like the idea of being able to back up and play from those backups, given that the Playstation disks were quite costly at the time.

It was also around this time that faster CD-ROM drives began appearing on the market. First came the 2x drive, then followed 4x, 8x, 12x & 16x drives and so on up to 52x drives. Things are going the same way with DVD drives today, with 22x drives the current flavour.

The new speedier models brought their own problems though. On more than a few occasions, I was called out soon after installing a new optical drive to complaints of noise and it not working properly. In all those cases, old and obviously cracked or damaged disks had literally blown to bits inside the drive, damaging it in the process.

It was sometimes a tough call as to which way to go when it came to replacing the dead unit – was it a warranty job or was it the client's responsibility (especially if the disk was known to be defective)?

LG plasma TV

This next story could also have been titled "Waste not, want not". It comes from P. C., a retired electrical engineer from One Tree Hill, SA. Here's how he tells it . . .

I was brought up in an era when, if something broke, you tried to fix it. It wasn't always economical to do so

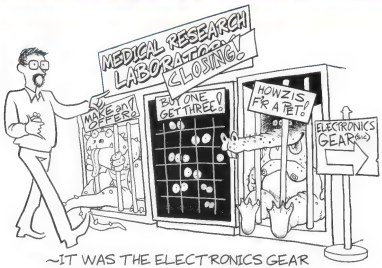
of course but it gave me the satisfaction of knowing that I had extended a device's useful life and saved it from the scrap heap. It always seems such a waste to throw away all the metals and plastics that something is made of, especially as the Earth's resources are not unlimited.

It was in this spirit that I approached the repair of an LG 106cm (42-inch) plasma panel TV (RT-42PX11) which was given to me by my son-in-law. This screen was larger than my own CRT TV but it was a 2006 model which had been superseded many times, even though it had good resolution. If I could fix the flat panel, I could use it with my HD set-top box and discard my dinosaur CRT set.

The plasma panel had died with a click from the rear when the set had been switched on. My first move was to lie the panel face down on the kitchen table and take the back off. This revealed a number of PCBs. Some boards were related to input signal processing while one was obviously the main power supply PCB. Three others drove the plasma panel itself.

Each of these latter PCBs had glass fuses and the fuse on the YSUS board had blown. This immediately narrowed down the problem to this particular board.

A close examination of this board revealed some heavy discrete com-



ponents (electrolytics, transformers and transistors) and a large heatsink (about 75 x 50mm) obscuring what was probably a special-purpose IC. Initially, I thought that I could measure the voltages on the major components but the system was under microprocessor control and wouldn't switch on because of the fault.

Not having a circuit diagram was a hindrance as well, so I looked for one on the net. I eventually found a source and downloaded the manual. However, I was disappointed because it didn't detail anything about the three plasma panel PCBs. Apparently, these boards are proprietary and are not regarded as serviceable.

In the end, it seemed that the only way to repair the unit was to buy a new YSUS board. There were two numbers on the PCB but the number etched into the board is not the one used for ordering. Instead, a sticker attached to the board gave the part number as "YSUS 6871QYH029A".

A Google search turned up a source for this PCB from Big Warehouse. The site also provided some additional advice that the available PCB "6870GYE008C" was the correct replacement PCB for the one I wanted.

Hoping that the advice was good, I ordered a new board and it arrived quite quickly. To install it, I had to re-attach all the other boards and I hoped that the new one would be OK after all my work. I switched on and was gratified when the panel sprang to life as good as new.

Afterwards, I cut away the large IC on the old PCB and removed the heatsink to see what it was. There were four large slices of silicon, presumably transistors, on the IC, two of which had exploded. I was glad I had not wasted any more time on the old PCB as it would not have been possible to replace this unique IC.

If I get another five years out of the unit for an outlay of $240, I will have done well. At the same time, the set has been kept from adding to our ever-growing electronic waste problem.

The ultimate multimeter

A. L. of Turramurra, NSW recently had an unusual failure in a high-end digital multimeter. Here's what happened . . .

A friend called me excitedly to tell me that a local medical research lab was closing because of lack of government funding and that we could visit them the same day to have a look at all the equipment for sale.

With business being quiet, I decided I could leave the place for awhile, so we made an appointment with the accountant at the lab. It was the electronics gear that I was really wanted to see and one item that did interest me was a Tektronix 60MHz 224 oscilloscope which handles up to 1000V peak and is only slightly bigger than a house brick! The price was reasonable so I agreed to pick it up at a later date, when I had some ready cash.

A couple of days later, the accountant rang and asked when I was coming to collect it. I went straight down to meet him and he explained that they now had to clear out the lab in a week and if I would agree to pay an extra $200, I could have all the other instruments no-one wanted.

This seemed like a bargain as there was a very large digital multimeter, a digital counter and a large, heavy dual-tracking variable power supply. Unfortunately, Mrs Serviceman was not impressed since space is somewhat at a premium in our workshop.

The large multimeter was an HP/Agilent 3458A and the functions of its various buttons and controls were not immediately obvious. As a result, I spent some time wading through the three large manuals supplied with the instrument before I could even do a simple voltage measurement. I also "Googled" it and found, to my astonishment, that the same instrument was being sold for up to $8000.00.

By now, I had spent an inordinate amount of time learning how to use it but had no idea as to whether I would ever need such a super-accurate and sensitive device – apart from checking out my other multimeters. The 3458A measures down to 10nV DC and 1pA and can measure RMS voltages at frequencies up to 10MHz. It is fully programmable and is apparently the "ultimate multimeter".

Now that I owned it, I just had to use it and so I always started it up as soon as I'd opened the workshop, to ensure sufficient warm-up time. And then one day, while I was repairing a microphone mixer for an old rock star from the 60s (another story), I became aware of the presence of thick black smoke. Unfortunately, it wasn't com-

This view shows the IEC socket/EMI filter at the back of the HP multimeter. The EMI components are housed in an oil-filled cover.

ing from the microphone mixer but out of every pore of my prized HP multimeter!

I quickly turned off the switch at the front of the instrument but the smoke came out even heavier! It wasn't until I whipped the mains plug from the socket that the smoke stopped.

I was so dispirited by this that I just left it in place for a couple of days before plucking up the courage to open it up. With all that smoke, experience told me that such a sensitive instrument must have suffered a terrible blow and may never display a nanovolt again.

My fear was that the power supply had failed and taken everything else out with it but the fuse was still OK. Then, remembering that the on/off switch had had no effect, I suspected some sort of switch failure, possibly caused by excessive current welding the contacts together so I checked it out. To my surprise, the switch was perfect!

So why did the smoke still issue forth when the switch was off? It didn't take long to figure out that the only components before the switch were the fuse and the IEC socket. And the latter looked pretty black!

In this case, the IEC socket is an EMI power-line filter type. It contains a filter that's based on a network of inductors and capacitors in an oil-filled shell and is designed to reduce line-to-ground (common mode) interference.

There was nothing for it but to remove it. However, that was easier said than done because it's riveted into a confined space and I had to drill out all the tiny rivets before I could slide it out of the case.

When I got it out, I immediately noticed some oil in the area below where the socket had been mounted. These sockets are oil-filled for cooling but because some of the oil had leaked out, the internal components had apparently overheated and brought the remaining oil to its "smoke-point".

As far as I can discover, HP/Agilent don't list a replacement part for the IEC socket. I guess no-one ever suspected it would ever wear out, which is why the engineers designed it to be riveted permanently to the chassis.

In the end, I replaced the faulty socket with a local version, after which the instrument fired up and passed all its (very complicated) self-checks – much to my delight.

That was some time ago now and it has worked ever since. It really is an excellent instrument and is the last word when it comes to checking other multimeters, some of which can show errors of 20% or more.

My friend, an electrician who paid good money for a "professional" multimeter, was shocked (no pun intended) to discover that it was reading 0.5V DC when it should have been showing 50V DC from my benchtop supply!

"Better throw it out before you kill yourself", I warned him. We tend to toss multimeters around in the toolbox without realising they can be damaged, so it was lucky he had it checked!

Since then, I have never left any device with one of those IEC/filter sockets switched on and left unattended. And at knock-off time, I always switch all my instruments off at the mains and remove the plugs as well. It's better to be safe than burn the house down! SC

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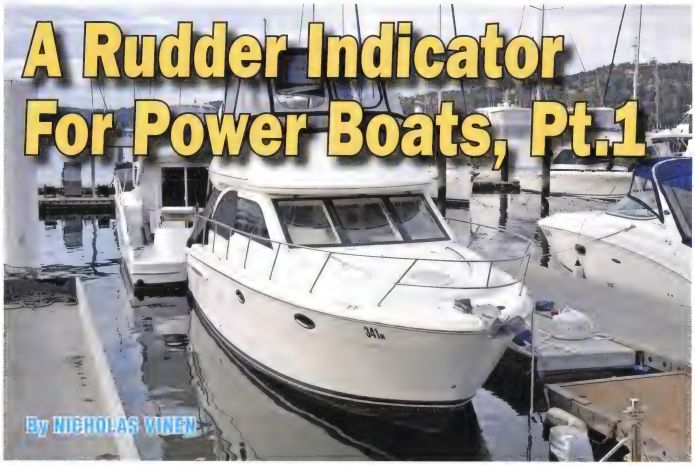
A Rudder Indicator For Power Boats, Pt.1



By NICHOLAS VINEN

Manoeuvring a medium-sized or large boat at low speeds can be very difficult and it is even more difficult if you don't know where the rudder(s) is pointing before putting the engine(s) into gear. Trouble is, in most boats, after swinging the wheel back and forth several times, you have no idea. Take the guesswork out of steering with this Rudder Position Indicator.

HERE IS A typical scenario. You are reversing your flybridge twin-engined cruiser into a berth (doesn't everyone have one of these?). You must do it at low speed (pretty obvious!) and you can't use the rudder to steer with since rudders don't work at low speeds. The only way to steer is to use the motors.

Normally, in a twin-engined boat, you make sure the rudders are centred and then you manoeuvre the boat by nudging the motors into and out of gear and using very judicious (tiny!) amounts of throttle or none at all. For example, if you are going forward, you can steer to port (left, if you're a landlubber) by putting the port engine into reverse and the starboard engine into forward gear. Or you might just leave the starboard engine in neutral while nudging the port engine in and out of reverse gear.

Going in reverse is a whole different ball-game. Now you are looking at the rear of the boat while you manoeuvre it into a narrow berth. In this case, if you want to steer to the left going backwards, you put the starboard engine into reverse and the port engine into forward . . . or combinations of those settings. All the while, you have to cope with the effects of currents and wind. It can be a nightmare.

It can be even harder in a single-engined boat. The rudder still doesn't work at low speeds and you don't have the luxury of two motors to do the steering. In this case, you do have to use the rudder but in order to get the boat to respond to the rudder, you have swing it hard over, in one direction or the other, and give the motor a quick stab of power in forward or reverse gear to push the stern of the boat in the required direction. Sounds tricky, doesn't it? Well, it is.

Going back to the twin-engined boat for a moment, before you can start these low-speed manoeuvres, you must have the rudder centred. But since typical boats require many turns from lock-to-lock, it is almost impossible to know when the rudder is centred. The practical way to do it, is count the turns from lock-to-lock and then halve it, to centre the rudder. So if it is six turns from lock to lock, you turn the wheel fully to port or starboard and then wind the wheel

back by three turns. Trouble is, it's easy to lose count when you're winding the wheel back and forth.

How much easier it would be if you had an electronic rudder indicator! Commercial rudder indicators are fitted to some boats but they are very expensive.

So that was the brief. The skipper of SILICON CHIP can't steer his boat (hope I won't get into too much trouble for this . . .) and he wanted an electronic indicator. Being the autocratic type that he is, who was I to argue? His justification is that the project would have other applications, so here is the result.

This Rudder Position Indicator consists of two units, each of which mounts in a small sealed box with a transparent lid. The sensor unit monitors the movement of the rudder arm and transmits information to a receiver unit via a UHF radio link at 433MHz.

The receiver display unit is portable so that it can be moved from the flybridge driving position to the helm inside the cabin. It shows the rudder position using an array of high brightness LEDs, with adjustable brightness to suit indoor and outdoor use.

Specifications & Performance

Rudder Position Resolution ..... seven steps, plus centre indication
Sensor Type ..... magnet and reed switch
Communication Method ..... 433MHz UHF digital wireless transmission (Amplitude Shift Keying)
Range ..... approximately 20m (depending on antenna orientation and obstacles)
Power source ..... 4 x AAA cells or external 12V supply
Battery life (sensor unit) ..... approximately two years with 4 x AAA cells
Battery life (receiver) ..... approximately two years on standby or 2-8 hours in use, depending on LED brightness
Size (each unit) ..... 105 x 75 x 40mm with a protruding 15cm whip antenna

Features

The rudder display can show one of seven positions: three steps to port, three to starboard and one when it is centred. The port, starboard and centre positions use different LED colours to make the direction more obvious at a glance. For extra precision in setting the rudder straight ahead, the middle LEDs flash when the rudder arm is directly over the central sensor.

Both the sensor and receiver units are fitted with short whip antennas (about 15cm) to provide sufficient range for use on larger boats. In most boats, the hydraulic steering arms are located in a compartment called a "lazarette" and this may or may not be lined with aluminium foil coated insulation, to cut down noise and heat. In this case, it may be necessary to run a coaxial cable from the sensor unit to a whip antenna mounted outside this compartment, to allow the signal to reach the helm position(s).

The same comment applies if the boat has an aluminium or steel hull.

Both the sensor and receiver units can be powered from an internal battery (which can be rechargeable) or from an external 12V power source. An external power source can also be used to trickle charge the internal batteries. The approximate charge state of both batteries is indicated on the display unit.

The sensor unit is always powered, so you don't have to switch it on and off each time. Even so, its low current drain means that it will run for at least a year on four AAA cells. Just how long depends on how often you use it and the cell type used. If you use good-quality alkaline cells, the transmitter battery could last two years or more.

Many boats have a 12V lead-acid battery in the lazarette and in that case, you can omit the sender unit's

The sender unit (left) uses seven reed switches to detect the rudder position. It transmits data to the receiver unit (right) via a 433MHz wireless link.

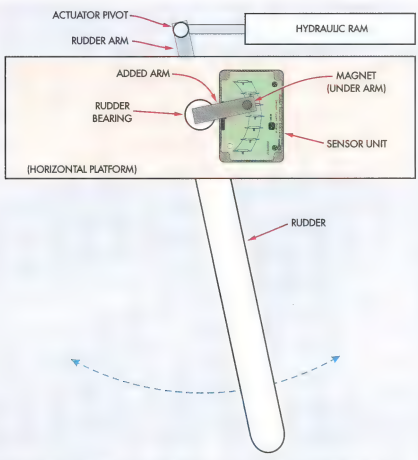


Fig.1: how the sensor unit is arranged. It's mounted on a platform and is activated by a magnet on the underside of an arm that's attached to the rudder shaft.

internal battery and use that as a power source instead.

The UHF link makes installation easy; there is no need to run wires from the rudder to the helm which can be a major task in a typical large power boat.

Design concept

The first aspect we considered was how to sense the rudder position. There are four obvious sensor types to choose from: a rotary switch, a potentiometer, an optical sensor or reed switches. In each case, either the sensor needs to be attached to the rudder shaft or an arm must be attached to the shaft with the sensors arranged in an arc above or below it, so that the arm triggers one at a time.

Rotary switches and potentiometers tend to wear out fairly quickly with continuous use and they can also be fouled by water, grease or dirt in a marine environment, unless they are fully sealed. An optical sensor is a better choice but is the most power-hungry option and it also requires the most complicated wiring, as both the light source(s) and sensor(s) require power.

So we settled on reed switches, with a magnet attached to a cranked arm that is mounted on the rudder shaft. Seven reed switches are arranged in an arc below the arm so that as the arm moves, the magnet passes over them, closing each reed switch in turn. Fig.1 illustrates this arrangement.

While it is possible to design these circuits using discrete logic and special-purpose ICs (in fact, we initially tried to do just that), there are several advantages to a microcontroller-based solution. First, if we use a microcontroller in each unit, fewer parts are required. Since we want to fit the display unit into a small box with an internal battery (so it's easily portable), this is important.

Also, because the microcontroller in the sensor unit can drive current through the reed switches intermittently, the battery drain can be kept very low.

So for the final design, each unit is based around a microcontroller which does virtually all the work, in combination with a wireless transmitter or receiver module. Most of the time, the micros are in a low-power sleep mode, keeping the battery drain down to about 15μA (including current for the regulator). When active, the micro wakes up and performs the necessary tasks before going back to sleep.

Each unit comprises two PCBs: a lower control board which hosts the battery, micro and most other components, and an upper board which hosts either the reed switches (sender unit) or the display LEDs (receiver unit). All boards are the same shape and size and fit snugly into the sealed boxes, so only the top board is visible through the clear lid.

Basic operation

For an overview of how the two units are configured, refer to Fig.2, the block diagram. The sensor unit (left) contains the reed switches for rudder position sensing and the microcontroller to monitor them. When the switch state changes, the micro powers up the 433MHz transmitter module and sends a data packet containing the new position. This packet is amplitude shift keyed (ASK) and bi-phase encoded.

The receiver/display unit (right) is portable and only listens for packets when it is switched on. When it receives a valid packet, the microcontroller decodes it and extracts the new rudder position. It then displays this position by determining which row of high-brightness LEDs is lit.

The display unit incorporates a boost regulator. This is necessary to drive the series strings of five LEDs that form the main display. With a typical forward voltage of around 2V, at least 10V is required to drive each string (slightly more due to the 100Ω series current limiting resistor they share).

The boost regulator develops roughly 12V at 20mA when the LEDs are lit, from a nominal 6V battery (it can operate down to about 3V). It can also run off an external 12V supply, in which case very little or no boosting is needed. In this case, a series resistor in the power supply input ensures that the LED voltage doesn't exceed 12V, even if the supply voltage is up to 14.8V (eg, when a lead-acid battery is on charge).

Note that while the wireless mod-

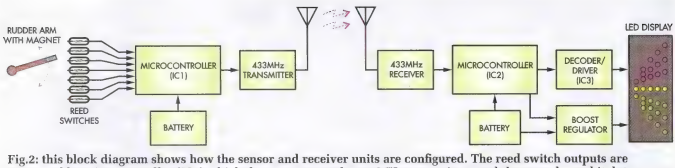


Fig.2: this block diagram shows how the sensor and receiver units are configured. The reed switch outputs are processed by microcontroller (IC1) which then powers up the 433MHz transmitter module to send a 16-bit data packet on the new rudder position. This signal is picked up by receiver and processed by another microcontroller (IC2). This then drives a LED display (consisting of series LED strings) via decoder/driver IC3.

ules are referred to as operating at 433MHz, the actual frequency band used is 433.05-434.79MHz.

Sensor unit details

The micro in the sensor unit is in low-power "sleep" mode almost all the time. Its 32kHz watchdog timer (WDT) is continuously running and this "wakes it up" several times a second (maybe it sleeps quite poorly!) to check the reed switch state. To do so, it turns on an internal pull-up current source for each input and checks the voltage. The current sources are then immediately disabled and remain off until the next time, to conserve power.

Further action is only taken if the switch states differ from the previous reading. Otherwise, the period the micro spends running is very short and the power consumed during these periods is negligible.

When a change in reed switch state is detected, the 433MHz transmitter module is powered up. Several 16-bit packet pairs are transmitted with a short delay between each, in case interference corrupts one or more of the packets. Each packet pair encodes the updated rudder position, battery charge state and a unique identifier number, which is randomly generated when the battery is inserted.

Once five complete packets have been sent, the transmitter is shut down and the device goes back to sleep until another rudder movement occurs.

Packet protocol

The format of the 16-bit data packets is shown in Fig.3. The bi-phase data is encoded by the microcontroller before being sent to the transmitter module, which modulates the amplitude of its 433MHz RF output accordingly.

Each packet contains 14 bits of data along with two start bits. With bi-phase encoding, a zero is encoded with one level change between bits (low-to-high or high-to-low) while a one is encoded the same way but with an additional level change in the middle of the bit.

The advantage of bi-phase encoding is that the bit timing and the data are encoded together, so the transmitter and receiver can re-synchronise the timing for each bit. The receiver records the signal level one quarter and three quarters of the way through each encoded bit and if they differ, it records the bit as a one. It also times the level changes before and after this, to determine when to sample the next bit.

The first data bit value determines the meaning of the following three bits. If this first bit is a zero then the next three encode the rudder position, with 0-6 indicating one of the seven possible positions and seven indicating that the centre reed switch has opened but no other switches have closed. This is used to indicate whether the rudder is precisely centred.

If the first data bit is instead one, then the following three bits encode the transmitter's battery state. Zero means that it is fully discharged, while seven indicates full charge.

In either case, the next eight bits contain the transmitter's unique identifier (ID), which is generated based on random noise sampled by the ADC module. This number does not change unless the battery is removed. The receiver remembers the transmitter's ID and ignores any packets from transmitters with different IDs, until it too is power cycled.

Finally, there are two checksum bits which are the bottom two bits of the total number of ones in the transmission (ignoring the start bits and the checksum). This is similar to parity and it allows the receiver to detect if any single data bit has been scrambled during transmission (or in some cases, when multiple bits are affected).

If the checksum does not match the received data, the packet is ignored. This reduces the chance of an incorrect display as the result of interference or marginal reception.

Display unit details

When it is not in use, the micro in the display unit is in low-power sleep mode and so the drain on the battery is minimal. When the single pushbutton

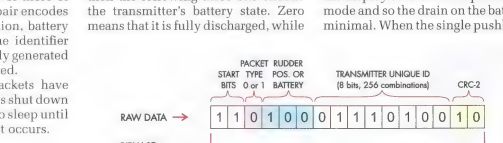


Fig.3: the 16-bit data packet format. The data is bi-phase encoded and each packet contains two start bits and 14 bits of data. Bits 4-6 encode either the rudder position or the battery state, depending the state of the first data bit (0 = rudder position, 1 = battery state).

Table 1: Battery Voltage Jumper Options

Battery type	JP1 pins shorted
Four non-rechargeable AAA (nominal 6.0V)	1&2
Four rechargeable AAA (nominal 4.8V)	3&4
12V lead-acid (nominal 12.9V)	none (or 2&3)

is pressed, the micro wakes up and activates the boost regulator, which it controls via software. This generates power for the LEDs (12V) and the 433MHz receiver module (5V, derived from the 12V rail via a linear regulator).

Initially, only the battery state LED(s) are lit (indicating the unit's own battery voltage) and it waits for a data packet. Upon reception, assuming that it is valid, the display is updated to show the new rudder position. The display remains in this state until the rudder moves again and a new packet is received, or the unit is shut off (either manually or through a long period of inactivity).

Since the transmitter's battery state is sent at the same time as the updated rudder position, this can be shown on the display unit. It is distinguished by the micro flashing the battery level LEDs while it is being displayed. After a few seconds, the flashing ceases and the display unit's own battery state is once again shown instead.

If no new packets are received for 10 minutes and the button has not been pressed, the unit automatically shuts down to conserve battery power. It can also be turned off by holding down the pushbutton for about one second.

Short presses on the button cycle through three possible LED brightness settings, which suit indoor use and outdoor use, with and without direct sunlight. On the lower brightness settings, the battery lasts longer.

One additional feature we have hinted at helps you to tell whether the rudder is dead centre. When the magnet is moved away from the centre, the middle reed switch opens before any of the adjacent switches close. In this case, we don't know which way the rudder has moved, only that it is no longer centred.

Taking advantage of this, the middle (yellow) row of LEDs initially flashes when the central reed switch is closed. When it opens, a packet is transmitted which causes the flashing to cease. If the rudder is moved back to the centre again, the middle switch closes and so the flashing resumes.

Power supply options

As stated, both units can be operated without external power connections, using their internal battery only (four AAA cells). These can be rechargeable and with an appropriate connector, can be recharged without having to open the unit up.

Since the transmitter unit's battery should last more than a year, alkaline cells are a practical proposition and the unit can be opened to replace them. However, the batteries in the display unit only last a few hours if it is used at maximum LED brightness. So in this case, either external power or low self-discharge NiMH batteries recharged from 12V are the most practical options.

External power is practical for the transmitter, since it does not move and is usually located near a 12V lead-acid battery (its load on that battery would be minimal). On a boat with a single helm position, the receiver unit could be hard-wired too, although it's more flexible to run it from its internal battery.

If a charge connector is used for either unit, it should ideally be a sealed type, to prevent moisture ingress. If you use a regular connector, we recommend applying silicone sealant on the inside once it has been installed, to reduce the chance of water entering the enclosure.

The sensor unit has provision for a PCB-mount DC connector. If this is used, a hole must be cut into the side of the box. This is not recommended if there is any possibility of water being present where it is mounted.

Battery life

For either module, when the micro is in sleep mode, the continuous 15μA current draw works out to around 473mAh/year. At this rate, four 900mAh NiMH AAA batteries should last about two years. Rechargeable cells must be low self-discharge types or else their own internal discharge will be much higher than this and they will go flat if left uncharged for more than a few weeks.

Good-quality alkaline cells generally contain more energy than NiMHs so they should last even longer than two years.

The sensor unit's current increases to 15mA for about 100ms when the rudder position changes. This equates to an energy consumption of around 1mAh for every 2400 rudder position changes. If you take two trips a week and each trip involves 1000 position updates, that means a drain of just 43mAh/year, so rudder movements don't really figure into the battery life.

For the display unit, the situation is more complicated. Driving the high-brightness LEDs can consume 100mA or more continuously, depending on battery voltage and brightness setting. At this rate, with similar cells as we have described above, we would expect 6-9 hours of use per charge. Due to internal resistance and falling battery voltage, the battery life at full LED brightness will be more like 2-3 hours.

As you would normally only turn the unit on when leaving the marina (or dock) or returning to it, that should be more than enough for a single trip. It's probably a good idea to recharge the cells after each outing. It can be kept on trickle charge when it is not in use, so it's always ready to go.

When the display unit is switched off, the micro consumes about the same power as the sensor unit does. So a fully-charged battery will lose about half its charge per year if left untouched.

Sensor circuit description

The circuit for the sensor unit is shown in Fig.4 and the highlighted section shows the reed switches on the upper board.

The battery holder for the four AAA cells is on the lower board. They can be trickle charged from 12V via CON1 or CON2, depending on which is installed. CON1 is a 2-way terminal block which can be wired to a separate chassis power connector, while CON2 is a PCB-mount DC connector. The same connectors can be used for permanent power if the unit is hard-wired.

When trickle charging the battery, the 390Ω resistor limits the charge

current to about 20mA. Its value can be reduced if high-capacity cells are used, allowing them to charge faster. For example, if 900mAh AAA cells are used, a 220Ω 0.5W resistor increases the charge current to around 40mA.

In either case, the charge time for a completely flat battery is around 24 hours. In practice, the battery will normally be only partially discharged so eight hours should be sufficient.

If the module is to be powered permanently from a 12V supply (eg, an external lead-acid battery), use a 100Ω resistor instead.

A 500mA fuse protects the power source from a board fault. Schottky diode D1 provides reverse polarity protection (it drops less voltage than a standard diode). Zener diode ZD1 protects the circuit from voltage spikes which may occur when a lead-acid battery is on charge (due to load dumps and so on). If the spike is particularly bad, the fuse will blow, protecting the unit from damage.

REG1 regulates the incoming voltage down to 3V (or 3.3V depending on the exact type used). Microcontroller IC1 and the 433MHz transmitter module run off this voltage.

The LM2936Z regulator specified is designed for automotive use, so it is robust enough for a marine application. It has a quiescent current of below 15µA with a light load such as a micro in sleep mode. The micro draws less than 1µA in sleep mode, hence the low current drain when the device is idle.

Regulator stability is ensured by a 100nF input bypass capacitor and a 100µF output filter capacitor. While low drop-out regulators require capacitors with an ESR value within a certain range, the range in this case is very large (0.01-8Ω) so virtually any 100µF electrolytic capacitor is suitable. REG1's 3-3.3V output is also bypassed with a 100nF capacitor.

The microcontroller (IC1) is an ATTiny861. These are easy to obtain at a reasonable price and have all the necessary features for this application: low power consumption in sleep mode, plenty of program (flash) memory, an analog-to-digital converter (ADC) for battery voltage monitoring and enough digital I/O pins for our purposes.

The micro consumes less current at 3V or 3.3V than at 5V. Its ADC power supply (AVcc) is filtered with a 100Ω resistor and 100nF capacitor, removing

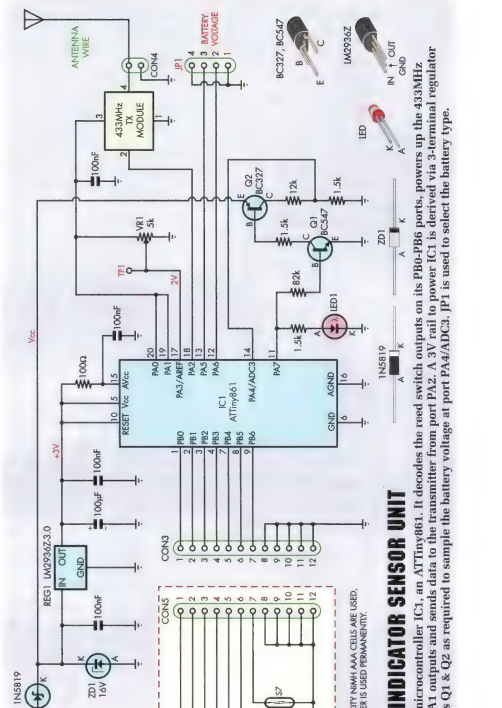
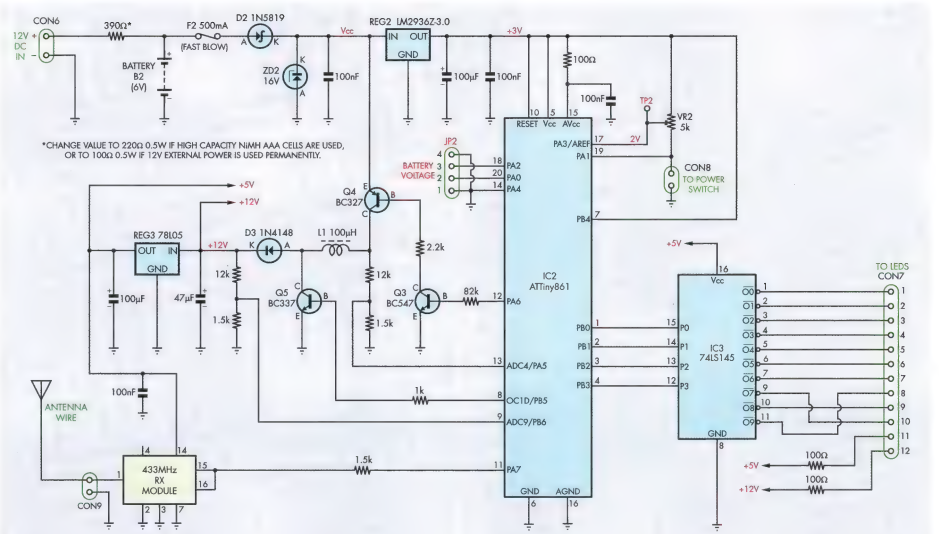


Fig.4: the sensor circuit is based on microcontroller IC1, an ATTiny861. It decodes the reed switch outputs on its PB0-PB6 ports, powers up the 433MHz transmitter module from its PA0 & PA1 outputs and sends data to the transmitter from port PA2. A 3V rail to power IC1 is derived via 3-terminal regulator REG1, while PA7 turns on transistors Q1 & Q2 as required to sample the battery voltage at port PA4/ADC3. JP1 is used to select the battery type.



RUDDER POSITION INDICATOR DISPLAY UNIT

Fig.5: the receiver circuit also uses an ATTiny861 microcontroller (IC2). The data from the 433MHz receiver module is fed to its PA7 port and processed, with the decoded binary data appearing at ports PB0-PB3. These drive a 74LS145 4-to-10 binary decoder with open collector outputs which in turn drive the LEDs on the display board (see Fig.5) via connector CON7. Inductor L1, diode D3, transistor Q5 and the 47µF capacitor at D3's cathode form a boost converter which is controlled from IC2's PA6 port using transistors Q3 & Q4. This provides a +12V rail for the LED display and drives REG3 to derive a +5V rail for IC3.

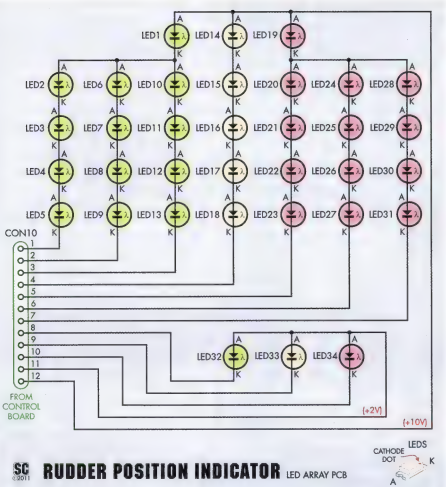


Fig.6: the LED array board consists of seven strings of series LEDs (LEDs1-31) to give a visual indication of rudder position plus three LEDs (LEDs32-34) to indicate the battery condition. It's driven from CON7 of the receiver board.

digital switching noise injected by the other circuitry and hence improving ADC conversion stability.

The reed switch sensors are connected to the PORTB pins PB0-PB6 (pins 1-4 & 7-9), via pin header socket CON5 on the upper board. IC1 has internal current sources for each reed switch which can be turned on and off by software. Each has a source impedance of 20-50kΩ, sourcing 60-150μA when enabled.

IC1's PA0, PA1, AREF, ADC3 and PA5-7 (pins 11-14, 17 & 20) are used to monitor the battery voltage. A jumper shunt placed on pin header JP1 tells the micro what type of battery is being used, so that it knows what voltage range to expect. There are three possible options, indicated by the different combinations shown in Table 1. The microcontroller (IC1) reads the jumper position using pins PA5 and PA6.

PA0-1 and trimpot VR1 provide the ADC reference voltage (AREF). This is set to 2V. No current flows through VR1 unless PA0 and PA1 are sourcing current (ie, they are driven high to +3V), saving power when the ADC is not in use. The ADC is only used for brief periods so the circuitry to supply AREF is only active during this time (and for one minute after power is applied, allowing VR1 to be trimmed).

The battery/supply voltage is sampled at the ADC3 pin, via a 12kΩ/1.5kΩ divider. This converts the battery voltage (0-18V) into a range which can be handled by the ADC (0-2V). As with the AREF divider, current does not flow through it unless the battery voltage is actually being read, to save power, as controlled by pin PA7.

This is driven high while ADC3 is being sampled, turning on NPN transistor Q1 and sinking current from the base of PNP transistor Q2, turning it on as well. This allows current to flow from the battery (after the fuse and diode D1) into the 12kΩ/1.5kΩ resistive divider and then to IC1's ADC3 pin. When PA7 is high it also drives a high-brightness LED (LED1), indicating that the transmitter is active.

Ports PA0 & PA1 also supply power to the 433MHz transmitter (Tx) module. With a 3V supply, the transmitter module receives at least 2.8V (0.2V is lost due to the internal resistance of the micro's output transistors).

When the transmitter is powered up, output PA2 is used to send the data burst to the transmitter module. When the transmitter is not powered, PA2 is kept low.

The antenna is a ¼-wavelength whip, measuring about 164mm and soldered to a PC pin on the lower board. This gives a useful range of approximately 20 metres, even with the user's body between the transmitter and the receiver. This can vary somewhat, depending on the obstacles between the two units and the relative antenna orientation.

Display unit

Figs.5 & 6 show the circuit for the receiver unit. Fig.5 depicts the lower board circuitry, while Fig.6 shows the LED array circuit on the top board.

The power supply for the receiver unit is identical to that used in the sensor unit, except there is no provision for an on-board DC connector. That's because this unit is more likely to be exposed to spray and such a connector would be too likely to allow water ingress.

As for the sensor unit, the 390Ω resistor in series with CON6 should be changed for use with high-capacity cells or permanent 12V power. This is important, since the receiver unit can draw significantly more current than the sensor unit. This resistor must not be omitted, otherwise the LEDs could be over-driven if the 12V battery supply is on charge.

Microcontroller IC2 is the same type as before but its role is a little different. The PORTB pins PB0-PB3 drive IC3, a 74LS145 4-to-10 binary decoder with open collector outputs. This in effect gives IC2 10 open-collector outputs, one of which can be driven low at any given time (or they can all be turned off).

The binary decoder's outputs can handle voltages up to 15V (although the off-state leakage current can be significant even at 10V; enough to dimly light LEDs). Each output can sink up

Parts List: Rudder Position Indicator

SENSOR UNIT

1 PCB, code 20107111, 98.5 x 68mm
1 PCB, code 20107112, 98.5 x 68mm
1 sealed ABS box with clear lid, 105 x 75 x 40mm (Altronics H0321)
1 433MHz transmitter module (Jaycar ZW3100, Altronics Z6900)
1 2-way mini terminal block, 5.08mm pitch (CON1)
1 PCB-mount DC connector (optional*) (CON2)
2 M205 fuse clips
1 M205 500mA fast-blow fuse
1 5kΩ sealed horizontal trimpot (VR1)
1 4 x AAA PCB-mount battery holder (Jaycar PH9270)
2 M2 x 6mm machine screws and nuts (Element14 507118/1419445)
4 AAA cells (Alkaline or NiMH) (optional*)
1 4-way pin header (JP1)
1 jumper shunt (for JP1)
1 40-pin header socket, 2.54mm pitch (cut down to 12-way [CON3] & 4-way sockets)
1 20-pin DIL socket
2 PC pins
1 200mm length 1.5mm diameter enamelled copper wire
1 300mm length 0.7mm diameter tinned copper wire
7 glass-encapsulated NO reed switches (Jaycar SM1002, Altronics S5150A)
1 reed switch trigger magnet
2 15mm tapped Nylon spacers
2 M3 x 20mm machine screws
2 M3 nuts
1 small crimp wire joiner
1 small IP67-rated chassis connector*

Semiconductors

1 ATTiny861 microcontroller programmed with 2010711A.hex (IC1) (Altronics Z5110 or Futurlec ATTINY861-20PU)
1 LM2936Z-3 ultra-low quiescent current linear regulator (REG1) (Digikey**)
1 BC547 NPN transistor (Q1)
1 BC327 PNP transistor (Q2)
1 1N5819 Schottky diode (D1)
1 16V 1W zener diode (ZD1)
1 high-brightness red LED (LED1)

Capacitors

1 100µF 16V electrolytic
4 100nF MKT

Resistors (0.25W, 1%)

1 82kΩ	1 220Ω 0.5W*
1 12kΩ	1 100Ω 0.5W*
3 1.5kΩ	1 100Ω
1 390Ω*	

* Depends on power supply chosen, see text
** Alternative part LM2936Z-3.3 (Element14 1564641)

DISPLAY UNIT

1 PCB, code 20107113, 98.5 x 68mm
1 PCB, code 20107114, 98.5 x 68mm
1 sealed ABS box with clear lid, 105 x 75 x 40mm (Altronics H0321)
1 433MHz receiver module (Jaycar ZW3102, Altronics Z6905)
1 2-way mini terminal block, 5.08mm pitch (optional*) (CON6)
2 M205 fuse clips
1 M205 500mA fast-blow fuse
1 5kΩ sealed horizontal trimpot (VR1)
1 100µH 250mA axial RF inductor
1 4 x AAA PCB-mount battery holder (Jaycar PH9270)
2 M2 x 6mm machine screws & nuts (Element14 507118/1419445)
4 AAA cells (alkaline or NiMH)
1 4-way pin header (JP2)
1 jumper shunt (JP2)
1 12-way header socket, 2.54mm pitch (or cut down a 40-way socket) (CON7)
1 20-pin DIL socket
1 16-pin DIL socket
2 PC pins
2 15mm tapped Nylon spacers
2 M3 x 20mm machine screws
2 M3 nuts
1 small IP67-rated chassis connector*
1 small IP67-rated momentary pushbutton switch (Jaycar SP0656, Altronics S0961)
14 ultra-bright 1206 or 1210 SMD red LEDs (Digikey 754-1165-1-ND)
14 ultra-bright 1206 or 1210 SMD green LEDs (Digikey 754-1162-1-ND)
6 ultra-bright 1206 or 1210 SMD yellow LEDs (Digikey 754-1166-1-ND)
1 200mm length 1.5mm diameter enamelled copper wire
1 300mm length 0.7mm diameter tinned copper wire
1 50mm length red light duty hookup wire
1 50mm length black light duty hookup wire
1 100mm length blue light duty hookup wire
1 small crimp wire joiner

Semiconductors

1 ATTiny861 microcontroller programmed with 2010711B.hex (IC2) (Altronics Z5110 or Futurlec ATTINY861-20PU)
1 74LS145 4-to-10 binary decoder (IC3)
1 LM2936Z-3 ultra-low quiescent current linear regulator (REG2) (Digikey**)
1 78L05 5V linear regulator (REG3)
1 BC547 NPN transistor (Q3)
1 BC327 PNP transistor (Q4)
1 BC337 NPN transistor (Q5)
1 1N5819 Schottky diode (D2)
1 1N4148 small signal diode (D3)
1 16V 1W zener diode (ZD2)

Capacitors

2 100µF 16V electrolytic
1 47µF 16V electrolytic
4 100nF MKT

Resistors (0.25W, 1%)

1 82kΩ	1 390Ω*
2 12kΩ	1 220Ω 0.5W*
1 2.2kΩ	1 100Ω 0.5W*
3 1.5kΩ	3 100Ω
1 1kΩ	

* Depends on power supply, see text
** Alternative part LM2936Z-3.3 (Element14 1564641)

to 80mA. Seven of the outputs (pins 1-7) are used to drive 5-LEDs strings, to indicate the rudder position, while the three remaining outputs (pins 8-10) drive individual LEDs to form a simple battery meter.

The series LED strings have a common anode which is connected to the 12V rail via a 100Ω current-limiting resistor. The total forward voltage for each string is around 10V (5 x 2V), so the maximum DC current per LED is around (12V - 10V) ÷ 100Ω = 20mA.

In practice, due to additional losses, such as the saturation voltage of the 74LS145's output transistors, the LEDs run at a slightly lower current than this. However, because we have specified very efficient LEDs, they are still very bright.

It's a compromise because we if we ran them at a higher current, they would dim somewhat as the battery discharged. That's because the boost regulator generating the 12V rail becomes less effective as the boost ratio increases.

A 5V rail is derived from the 12V supply using regulator REG3. This rail powers both IC3 and the 433MHz receiver module. This is a little wasteful of energy (its efficiency is 5/12 = 42%) but it allows us to operate the receiver even if the battery voltage is well below 5V. That can easily be the case with four standard cells, especially if they are rechargeable.

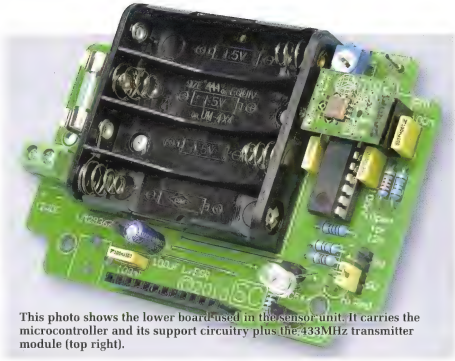
Note that REG3 has a 100µF output filter capacitor and this doubles as a bypass capacitor for IC3.

The battery indicator LEDs run off the 5V rail, since they are not connected in series. A second 100Ω current limiting resistor is shared between them; they run at a higher current of around (5V - 2V) ÷ 100Ω = 30mA.

Because only one of IC3's outputs can be active at any time, the battery LEDs must be multiplexed with the rudder display LEDs. Running them at a higher current allows them to be driven at a low duty cycle, keeping the rudder position LEDs as bright as possible with a high duty cycle.

Boosted supply

The boost regulator which develops the 12V supply consists primarily of inductor L1, NPN transistor Q5, diode D3 and a 47µF capacitor (at D3's cathode). The voltage across the 47µF capacitor is fed back to the micro via a 12kΩ/1.5kΩ resistive divider, to pin ADC9. This allows closed loop control.



This photo shows the lower board used in the sensor unit. It carries the microcontroller and its support circuitry plus the 433MHz transmitter module (top right).

Transistor Q5 is driven with a 187.5kHz PWM signal from output pin OC1D (pin 8) via a 1kΩ resistor. If the 12V rail is too low, IC2 increases the PWM duty cycle to bring it up and vice versa.

PNP transistor Q4 allows the boost regulator to be switched off by interrupting the battery current to it. This is important since a boost regulator's output voltage can never be less than one diode drop below its input voltage and we need to turn the 12V rail fully off to conserve power in sleep mode.

Q4 is driven by NPN transistor Q3 via a 2.2kΩ resistor, with Q3 in turn driven from output pin PA6 of IC2 via an 82kΩ current-limiting resistor. When PA6 is low, Q3 is off and so is Q4, so no voltage is applied to the boost regulator.

Q3 and Q4 also control the current flow through the resistive divider which is used to monitor the battery voltage. This involves another 12kΩ/1.5kΩ divider, the output of which is monitored by the ADC4 port of IC2. This is done so that the power consumption is reduced when the unit is not operating.

Battery monitoring

The display unit has similar battery monitoring circuitry to the sensor unit. The connections are slightly different though; for example, the trimpot (VR2) to set AREF (VR2) is now permanently connected to +3V rather than ground, so the other end must be pulled to ground by IC2's PA1 port to allow the ADC to operate.

PA1 also serves as a digital input to detect presses of the pushbutton switch wired to CON8. In this role, VR2 acts as a pull-up resistor and pressing the button pulls PA1 low, which is detected by the microcontroller. If the power is off, this triggers an interrupt which wakes the micro up. If it is already awake, it uses an internal timer to determine the length of the press; longer presses send it to sleep while shorter presses step through the LED brightness settings.

As with the sensor unit, a jumper shunt on 4-pin header JP1 determines the expected battery voltage – see Table 1.

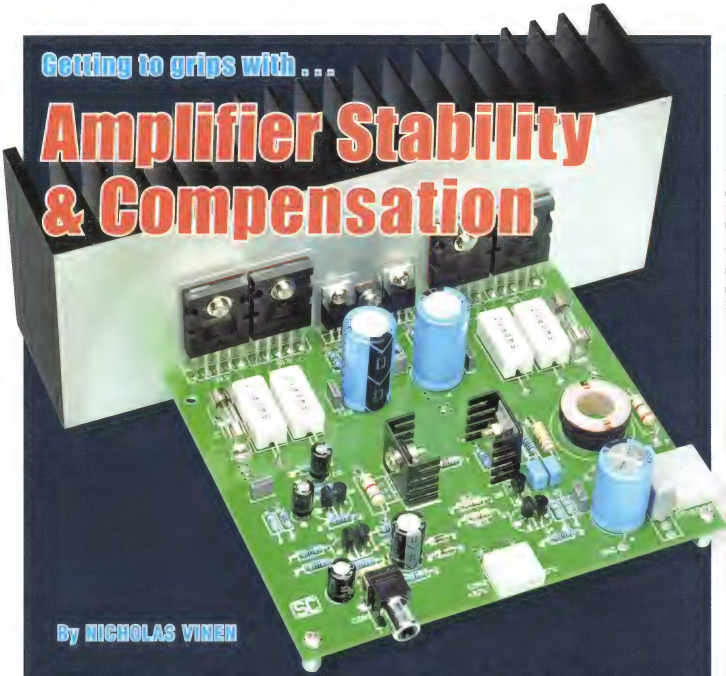
When the 433MHz receiver (Rx) has power (ie, when the boost regulator is switched on), data is fed through to PA7 (pin 11) of IC2. Since the receiver runs off 5V and the micro off 3V, the receiver's digital output can swing up above IC2's power supply voltage. This causes PA7's clamp diode to conduct and the 1.5kΩ series resistor limits the current which flows under this condition.

As with the transmitter, the receiver's antenna is soldered to a PCB pin on the lower board. It is orientated so that the unit can be held with the LEDs facing the user while it is operating.

That's it for this month. Next month, we will give the full assembly details and explain how to set up and test the two units. We will also give instructions on installing them in a boat. SC

Getting to grips with ...

Amplifier Stability & Compensation



By NICHOLAS VINEN

Elsewhere in this issue, we present the updated Ultra-LD Mk.3 Audio Power Amplifier Module. It has a new frequency compensation arrangement which helps it achieve even lower distortion than the Mk.2 version. In this article, we explain why amplifier frequency compensation is necessary and how it works.

AMPLIFIER FREQUENCY compensation and stability are complicated topics about which books can be (and have been) written. These issues are important when designing or modifying audio circuitry, yet they are widely misunderstood. Here's a brief summary of the relevant fundamentals.

Negative feedback

Stability and compensation relate to systems with negative feedback. But initially, let's consider a power amplifier (or op amp) with its feedback network disconnected. We connect the inverting input to ground and apply a small signal to the non-inverting input, as shown in Fig.1(a). This is known as "open loop" operation.

Nominally, the output voltage is the

difference in input voltages multiplied by the open loop gain which can be as high as one million (120dB). So a 1µV RMS input signal could result in a 1V RMS output signal.

Amplifiers operated in this mode aren't very linear which is another way of saying that they produce a significant amount of harmonic distortion. Also, this is far too much gain for most purposes and it varies from device to device.

Closed loop operation

If we feed a portion of the output signal back to the inverting input to apply negative feedback, the amplifier now operates in "closed loop" mode. The simplest method is to connect the output directly to the inverting input, as shown in Fig.1(b).

Assume for a moment that we have an "ideal" op amp. It has zero input bias current, infinite open loop gain at all frequencies, zero output impedance and no phase shift (ie, no signal delay) from input to input.

If we configure it as in Fig.1(b), whenever the input signal swings positive, the input voltage difference ("+" - "-") becomes positive. This is amplified by a huge factor and so the op amp's output swings towards the positive rail.

However, it stops when the output voltage equals the input signal voltage, as the input voltage difference is then zero. Similarly, if the input signal swings negative, the input voltage difference becomes negative so the output voltage decreases, tracking the input signal perfectly. Hence, this circuit is known as a "voltage follower".

Now consider what happens with the same circuit if we use a real op amp, which has a very high but finite open loop gain, say 1,000,000 times. We then apply 0V DC to the non-inverting input followed by a step change to +1µV. Shortly after that change, the output swings positive, towards 1V (ie, 1µV × 1,000,000).

But again, this positive slewing slows and then stops before the output gets to 1V because the inverting input voltage approaches that of the non-inverting input. The differential input voltage approaches but does not reach zero. The output (and thus the inverting input) settles at around 0.999999µV.

We know this because the input voltage difference is then 0.000001µV and this, multiplied by the open loop gain, is 1µV (ie, almost exactly the output voltage). So in reality, the output tracks the input with an error factor of ***1 ÷ open loop gain***. Higher open loop gain means better accuracy, explaining why ideal an op amp would have infinite open loop gain.

AC signal non-linearities are also reduced by the same factor (at low

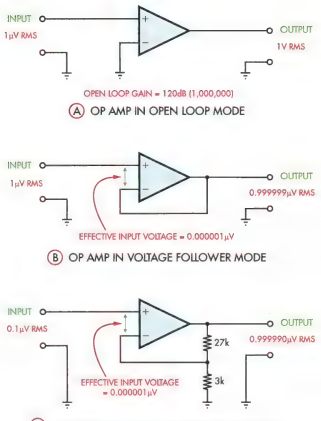


Fig.1: (A) an op amp operated in open loop mode, with a large but ill-defined gain and poor linearity; (B) an op amp configured as a voltage follower, operated in closed-loop mode with a gain of one; (C) closed loop operation with a fixed gain of 10 (the output accuracy and bandwidth are reduced compared to unity gain).

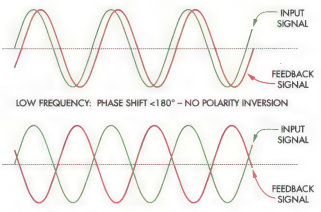


Fig.2: (top) at audio and low supersonic frequencies, amplifier feedback is in phase with the input signal and so negative feedback operates normally. At high frequencies (bottom), the feedback signal phase shift (delay) increases and eventually the feedback becomes positive, thus destabilising the amplifier.

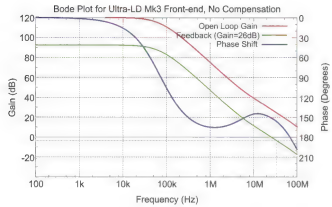


Fig.3: gain and phase (Bode plot) for a simple two-stage differential amplifier circuit with no Miller capacitor. It is marginally stable with a gain of 20 and not stable at unity gain. Note that there are two different vertical axes.

frequencies), vastly improving the distortion performance compared to open loop operation. At higher frequencies, the distortion cancellation becomes much less effective for various reasons, some of which will be explained later.

Fixed gain operation

We can achieve a fixed gain by dividing down the output voltage before applying it to the inverting input. Fig.1(c) shows how the gain is set to 10. Now let's imagine a +0.1μV step change is applied to the non-inverting input (one tenth that of the previous example).

Again, the output swings positive. This time, the output reaches 0.999990μV before the inverting input settles at about 0.099999μV. Again the open loop condition is satisfied, ie, the input voltage difference (0.000001μV) multiplied by the open loop gain equals the output voltage, more or less.

While the input voltage difference and output voltages are the same as the last example, now the output voltage is low by 0.000010μV or 10 times as much. That's because the output error is divided by the feedback network and so cannot be compensated for as effectively.

So for an amplifier with negative feedback, the DC input voltage error is constant and determined by the open loop gain (ignoring input offset and bias errors), while the output error factor is equal to ***closed loop gain*** ÷ ***open loop gain*** which in this case is 1/100,000.

The inverse of this is the feedback factor, ie, ***open loop gain*** ÷ ***closed loop gain***. A higher feedback factor means less DC voltage error and less AC signal distortion.

Any distortion produced by the amplifier circuit is also divided by the closed loop gain before being fed back to the input for correction. Thus it is the feedback factor which determines how well distortion is cancelled by negative feedback.

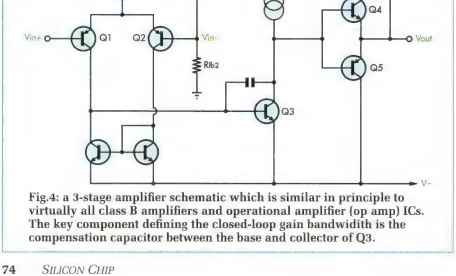


Fig.4: a 3-stage amplifier schematic which is similar in principle to virtually all class B amplifiers and operational amplifier (op amp) ICs. The key component defining the closed-loop gain bandwidth is the compensation capacitor between the base and collector of Q3.

Stability

While the negative feedback is applied virtually instantaneously with respect to audio frequencies, there is a time delay involved. This is due to capacitance and inductance in the amplifier circuit as well as charge storage effects in the transistors.

This fixed time delay (true to a first approximation) becomes a problem as the signal frequency is increased. You can see this effect in Fig.2. At low frequencies the delay in the feedback is slight but at a particular high frequency (and higher) the feedback is so delayed that it becomes positive feedback rather than negative. And if the feedback factor is greater than or equal to unity (ie, one) at this frequency, the output signal amplitude builds until it "bounces off" the supply rails (clipping). In other words, the amplifier becomes an oscillator.

Typically, the phase shift (ie, the time delay) reaches 180° at a high frequency, around 1MHz or more, and the resulting oscillation causes a variety of problems. A marginally unstable amplifier can operate more or less normally but has increased distortion and dissipation. It will get much hotter than it should because of cross-conduction of the output devices. This occurs because at high frequencies, they can't switch off fast enough.

Apart from that, oscillation in a marginally stable amplifier can cause major RF interference. And if the oscillation is high enough, it will burn out the power transistors, even in the absence of an input signal. So clearly, any oscillation is bad.

Preventing oscillation

If we arrange for the feedback factor to fall with increasing frequency, so that it is below one at the frequency where the phase shift reaches 180°, there won't be enough positive feedback for oscillation (but possibly still enough for overshoot and ringing in response to an input impulse).

The open-loop gain and feedback factor fall with frequency anyway, because the same capacitances and charge storage effects that cause the phase shift also act as low-pass filters on the signal. But this isn't usually enough to ensure stability.

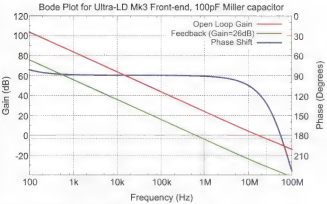


Fig.5: Bode plot for the same circuit as Fig.3 but with a 100pF Miller capacitor added. As shown, the phase shift is increased and the open loop gain reduced at low frequencies. It is unity gain stable.

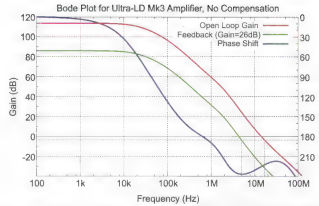


Fig.6: a Bode plot for a complete 3-stage power amplifier with no compensation. It is unstable even with a gain of 20 (26dB) due to the extra phase shift introduced by the output stage.

To demonstrate this effect, we ran SPICE simulations on the Ultra-LD Mk.3 amplifier circuit described in this issue. To measure the open loop gain and phase shift, we modified the circuit by removing the input and output filtering and disconnecting the feedback loop. The base of Q2 is connected to ground while the test signal is applied to the base of Q1. We used a 0.1mV RMS signal with a DC bias of about +3mV, to make the output swing symmetrically about ground.

The result of each simulation is a Bode plot. This is a graph with frequency on the horizontal axis and gain and phase on the vertical axes. One trace shows the open-loop gain in decibels (red) and the other, the phase shift in degrees (blue). We can judge the amplifier's stability and bandwidth from these plots.

(Bode plots are named after engineer Hendrik Wade Bode [1905-1982] who, while working at Bell Labs in the United States in the 1930s, devised a simple but accurate method for graphing gain and phase-shift plots).

We have added a third line to each graph which represents the feedback factor for a closed-loop gain of 26dB (green), as this represents the operating conditions of the Ultra-LD Mk.3 (and many other power amplifiers).

Because the plots are generated by simulation, they may not be 100% accurate. This is partly because we are not including parasitic capacitance and inductance effects. However, the results are quite similar to those of our prototype circuits, so we can draw useful conclusions, as long as we allow some margin for error.

For the output stage, we used transistor simulation models provided by On Semiconductor, which should be quite accurate.

Results

Fig.3 shows the Bode plot for the amplifier with no output stage buffer (Q10-Q15) and no compensation, ie, with the two 180pF 100V capacitors out of circuit. The output is taken from Q9's collector.

To explain further, Fig.4 shows the stripped down schematic of a typical power amplifier or op amp IC. Q1 & Q2 are the differential input transistors, Q3 (equivalent to Q9 in the Ultra-LD circuit) is the voltage amplifier stage and Q4 & Q5 are the output transistors.

The critical component which largely defines the amplifier's open-loop frequency response and phase shift is the capacitor between base and collector of Q3. This is often referred to as a Miller capacitor, which is a reference to the Miller effect of capacitance between the grid and plate of a triode; after John Milton Miller, in a paper published in 1920.

Getting back to Fig.3, the left vertical axis shows the gain in decibels and applies to the red (gain) and green (feedback) traces. The right vertical axis shows the phase shift in degrees and applies to the blue trace. The criterion for stability is that the amplifier gain must drop below unity before the phase shift reaches 180°. If the phase is more than 180° with a gain above unity, the amplifier will be unstable.

For Fig.3, showing a closed loop gain of +26dB, the feedback factor reaches unity at around 45MHz while the phase shift does not reach 180° so this configuration appears stable. The open loop gain is around 120dB for low frequencies but rolls off from a -3dB point around 40kHz.

Phase margin

The "phase margin" is computed as ***180° - phase shift***, at the point where the feedback factor reaches 0dB. In this case it is 30°. The higher the phase margin, the more tolerant the circuit is of additional capacitance at its output, as this increases the phase shift and can destabilise the amplifier. 45° is generally considered sufficient; anything less is regarded as marginally stable.

Compare this to Fig.5, which has been taken using a single 100pF Miller compensation capacitor between the base of Q8 and the collector of Q9. The open loop gain and feedback now begin to roll off at a much lower frequency, in fact from below 100Hz.

The phase shift has been increased to around 90° below 50kHz (a result of the severe low-pass filter action of the Miller capacitor). Since the open-loop gain is now well below unity at the point where the phase shift reaches 180° (80MHz or roughly the same as for Fig.3), this configuration should be stable for any gain of unity or more. The phase margin is much healthier at around 60°.

We can also measure the gain bandwidth for both cases, ie, the frequency at which the open loop gain reaches -3dB. It is around 22MHz for Fig.5 and the bandwidth for a closed loop gain of +26dB (20 x) is just above 1MHz. For the uncompensated circuit (Fig.3),

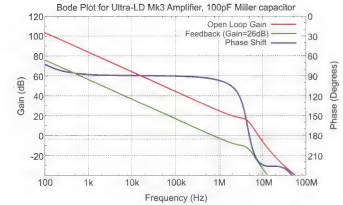


Fig.7: Bode plot for the same circuit as Fig.6 but with a 100pF Miller capacitor added. Once again, the phase shift is increased and the open loop gain is reduced at low frequencies. It is stable with a gain of 20 but not with unity gain.

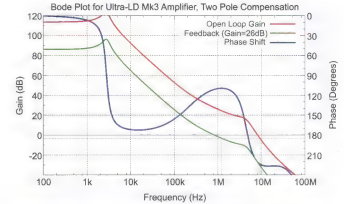


Fig.8: Bode plot for the complete amplifier with 2-pole compensation (compare this to Figs.6 & 7). It is also stable with a gain of 20 but open loop gain at audio frequencies is greatly increased at the expense of a higher phase shift above 3kHz.

the gain bandwidth is above 100MHz.

Theoretically, the bandwidth for a given gain setting is computed as ***gain bandwidth ÷ gain***. In other words, as the gain is increased, the bandwidth is reduced, unless the compensation arrangement is changed.

If we can change the compensation arrangement, we can adjust it to suit the closed-loop gain used, providing maximum bandwidth while maintaining stability. This is the main reason that some op amps provide pins for an external compensation capacitor (those with internal compensation are sometimes available in "decompensated" versions for use with higher closed loop gains).

Adding the output buffer

Now let's add the output stage (Q10-Q15) of the Ultra-LD Mk.3 module back into the equation. It's a unity gain stage, ie, simply a current buffer. In an ideal world, it would have no effect on open loop gain or phase shift but this is not actually the case.

Compare Fig.6 to Fig.3; the conditions are identical except for the presence of the output stage. It greatly increases the phase shift above 100kHz and so the frequency at which the feedback becomes positive has moved from 500kHz to about 200kHz. The open-loop gain rolls off at a slightly lower frequency, to a steeper slope. So with no compensation, the amplifier is even less stable with the output stage included, due to the additional signal delays.

For Fig.7, we add a 100pF Miller capacitor again. This arrangement is very similar to the Ultra-LD Mk.2 (August-September 2008) and many other power amplifiers. As with the earlier example (Fig.4), this pushes the feedback inversion frequency up but not as far; it is now around 5MHz.

The open-loop gain roll-off is virtually identical to that in Fig.5 except for the sudden drop above 5MHz, due to the transition frequencies of the driver and power transistors (these are specified as 50MHz but that is the -3dB point; the roll-off actually begins at a lower frequency).

As can be seen from the graph, for a gain of 26dB, the 100pF capacitor provides sufficient compensation, giving an excellent phase margin of around 80° and a bandwidth of about 1.5MHz. Interestingly, decreasing the closed-loop gain doesn't yield as much additional bandwidth as we might expect, due to the output stage running out of steam at 5MHz.

Two-pole compensation

Now we get to the crux of the matter. In the Ultra-LD Mk.3 amplifier described in this issue, we are using a 2-pole compensation arrangement for the first time. This replaces the single Miller capacitor with two series capacitors and a resistor from the "centre tap" to Q9's emitter. These capacitors can be different values but to simplify construction, they are both 180pF.

For those unfamiliar with the term "pole", in this case it refers to the effect of a single low-pass filter stage. Each low-pass filter pole adds a "knee" to the open-loop gain plot at the point where the frequency response rolls off. The pole also has an additional effect on phase shift.

The simulated effect of the 2-pole arrangement is shown in Fig.8. Comparing this to Fig.7 we can see that the open-loop gain and feedback factor both roll off at a much higher frequency than with single pole compensation. The roll-off occurs after a peak, at about 3-4kHz. The gain then initially diminishes at 12dB/octave, rather than the 6dB/octave which is possible with a single pole.

The result is that the feedback factor reaches unity at a similar frequency as for the single-pole scheme, despite the much higher corner frequency. The means a significantly greater feedback factor at higher frequencies in the audio band (in some cases by more than 30dB), allowing for better distortion cancellation. However, this benefit is limited by the additional phase shift introduced after the loop gain peak.

The phase shift after this peak approaches 180° (nearly 90° from each pole), reducing the benefit of the additional feedback at high audio frequencies. However, our tests show that this scheme still results in much improved distortion cancellation up to 20kHz.

The Bode plot does a good job of demonstrating how 2-pole compensation works. Below the gain peak, there is essentially no compensation, as the 2.2kΩ resistor shunts the feedback from Q9's collector, via the 180pF capacitor, to the negative rail.

Above the gain peak, the capacitor impedances drop so the 2.2kΩ resistance becomes less significant and both poles take effect. At very high frequencies, the capacitor impedances are so low that the resistor is taken out of the equation, giving the equivalent

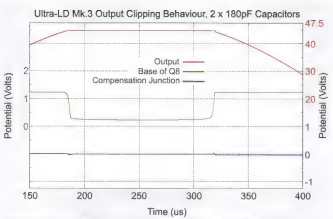


Fig.9: the behaviour of the complete amplifier when driven into clipping with a low load impedance (3Ω). The supply rails are at ±48V to simulate a power supply under load. With 180pF compensation capacitors, there is a small step as it recovers from the clip but no oscillation.

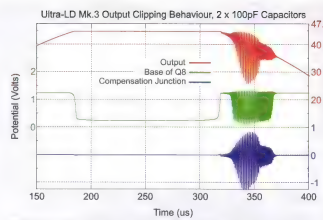


Fig.10: with 100pF compensation capacitors, the amplifier is stable during normal operation but not after recovery from clipping. Note how low the base drive for Q8 is during clipping, as the amplifier is operating in open loop mode. Recovery takes a finite period and triggers the oscillations which eventually die out.

of a single 90pF compensation capacitor. As a consequence, the phase shift returns to a little over 90° and the gain slope drops to -6dB/octave before the feedback factor reaches unity.

Ensuring stability

Looking at Fig.8, you may wonder why we can't reduce the compensation capacitors somewhat, since we apparently have quite a large phase margin (around 70°) and there is a reasonable gap between the point where the feedback factor reaches unity (900kHz) and where the phase shift reaches 180° (5MHz). This would increase the open loop gain and reduce distortion.

We performed this experiment on an Ultra-LD Mk.3 amplifier and examined its behaviour, in order to both confirm the accuracy of these simulations and to answer this question. The physical amplifier behaved essentially as predicted. It was stable during normal operation with ceramic capacitor pairs of 100pF, 120pF, 150pF and 180pF.

As we changed the capacitors, the distortion at 20kHz (with 20Hz-80kHz measurement bandwidth) varied over a range of approximately 0.0045% (100pF) to 0.0055% (180pF).

Things get interesting when we push the amplifier into clipping under load. With the 180pF capacitors (which we have selected for the final amplifier design), the waveform is simply clipped at the peaks where the output voltage reaches its furthest possible swing (see Fig.9). However, with the smaller capacitor values, there is parasitic high-frequency oscillation after the recovery from clipping (Fig.10). This oscillation is at 450kHz or so and it is worse with smaller compensation capacitors. It significantly increases the output current consumption, due to cross-conduction in the output devices and as a result, we managed to blow the output stage fuses more than once during these tests.

The reason that the amplifier behaves this way when it is normally stable is that once the clipping point has been reached, the amplifier is no longer operating in closed loop mode, as its feedback network is essentially out of action. For an amplifier with positive gain in clipping, the magnitude of the voltage at the inverting input (a divided down version of the output) has reached its maximum while the voltage magnitude at the non-inverting input continues to increase.

As can be seen from the figures, when this occurs for a positive excursion, the voltage from the base of Q8 to the negative rail drops dramatically (well below anything that's experienced during normal operation), so that the output will swing as close to the positive rail as possible. But when the output voltage needs to drop, this means that the voltage at this point must dramatically increase in order to resume normal operation.

This rapid change in base voltage, in combination with the compensation network from this point to Q9's collector (which is also in a state that does not occur during normal operation), can trigger oscillations in a marginally stable amplifier. If you look very carefully at Fig.9, you can see that the amplifier's output takes a short time to resume its normal slope after clipping; this same artefact is present in Fig.10 and the oscillation immediately follows it.

Similar oscillations occur after the output clips to the negative rail (not shown). However, in this case, the base-emitter junctions in Q8 and Q9 limit the maximum voltage at Q8's base to around 1.4V. As a result, the recovery is quicker and the oscillations are less severe.

Note that while Figs.9 & 10 are produced by simulation, they bear an uncanny resemblance to what we saw on our scope while testing the real thing. That the SPICE simulator is able to reproduce this behaviour gives us confidence in its accuracy.

Further research

If you want to investigate stability and compensation yourself, the SPICE netlists, command files and component models are available as a download from the SILICON CHIP website (SPICE_Amplifier_Stability.zip). You will need SPICE simulation software (eg, **ngspice** or **LTspice**, both of which are available for free) and some experience with circuit simulation.

We won't detail how to run the simulations here. Once you figure it out, it is easy to change component values and configuration and then produce new Bode plots to gauge the effect of those changes on amplifier stability and feedback. SC

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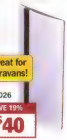

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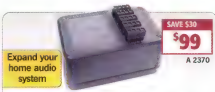

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(SC June '06) This compact generator creates 9 test patterns which are displayed on any device with a composite video input. This allows easy diagnosis of video distortion problems. Requires 9V battery.

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SAVE $50 K 6015 **$119**

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(SC Sep-Oct '08) A great value model railway controller offering remote control, pulse power for realistic low speed train movement, speed bargraph & adjustable braking inertia. 16-17V output up to 6A. A 1012 remote to suit $19.95. 240V operation.

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GPS Module	K 1131	$79

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K 2574 SAVE 12% **$79**

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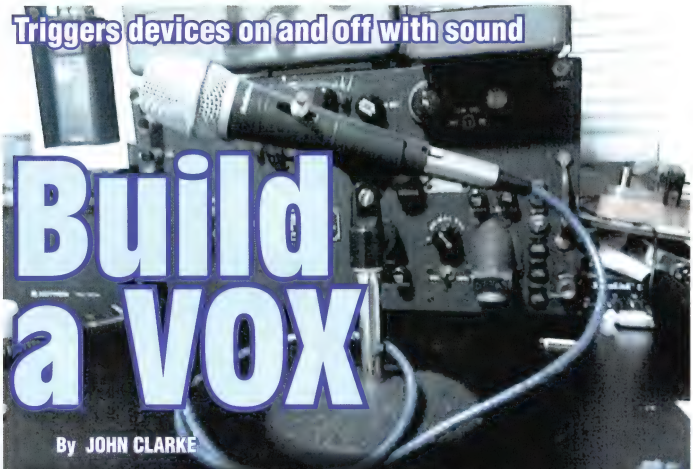
Triggers devices on and off with sound

Build a VOX

By JOHN CLARKE



Traditionally, VOX circuits toggle a transmitter on as you speak into a microphone and off again when there is silence. But VOX circuits can be used anywhere you want to turn something on when a sound occurs or you speak into a microphone. You could use it turn on a light, an amplifier or maybe even unlock a door.

VOX stands for Voice Operated eXchange and it is also the Latin word for 'Voice'. A VOX circuit switches on a relay whenever a signal reaches a set threshold. The relay switches off once the signal level drops below the threshold and after a short delay.

They are used in communications, public address systems, surveillance, security and general purpose electronics.

For communications, a VOX switches a transceiver from receive to transmit whenever the person speaks into the microphone. This frees the operator for other tasks as a separate switch is not needed to talk. Many intercoms and public address systems are also automated in a similar way.

A VOX circuit can be used to mute any sound until it reaches a set level. That way a public address system will ignore background noise and remain quiet, until someone intentionally speaks into a microphone. For security and surveillance, a recorder can be switched on whenever a noise is sensed by a microphone.

But it doesn't have to be a microphone which causes the VOX action. For general-purpose use, any audio signal can used to switch the relay.

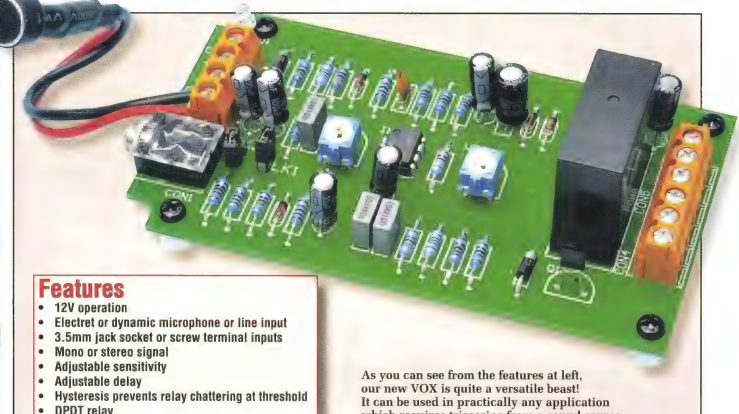
Our design

In line with the above comments, our VOX design has two inputs, both of which will accept the same types of audio input. First is a stereo 3.5mm jack socket which will handle both mono and stereo signals, while the second input is for mono inputs only and is via screw terminals.

You can connect an electret or dynamic microphone. Electret microphones require a bias voltage which can be selected with a jumper link (LK1). For stereo signals connected via the 3.5mm socket, a jumper link provides mixing of the left and right channels into a mono signal.

Signal sensitivity can be adjusted to cover a wide range from microphone levels up to line levels of 2V RMS. With sufficient signal, the relay switches on and remains on until the signal level drops to below a threshold level. An adjustable delay sets the time taken for the relay to switch off once this threshold is reached.

The relay has two sets of changeover contacts which will suit a variety of



Features

- 12V operation
- Electret or dynamic microphone or line input
- 3.5mm jack socket or screw terminal inputs
- Mono or stereo signal
- Adjustable sensitivity
- Adjustable delay
- Hysteresis prevents relay chattering at threshold
- DPDT relay
- Power and relay LED indication

As you can see from the features at left, our new VOX is quite a versatile beast! It can be used in practically any application which requires triggering from a sound source – and that sound source can itself be just about anything!

switching applications. LEDs are included for visual indication of power and of relay switching.

Because of the wide variety of possible uses for a VOX, our module is simply presented as a PCB which you can install to suit your application. Or if you wish, it can be fitted into a plastic "UB3" case measuring 130 x 68 x 44mm.

Circuit details

The VOX comprises a dual op amp (IC1) that functions as a signal amplifier and threshold switch. The relay is driven from the second op amp via a transistor.

Input signals come in via the 3.5mm jack socket (CON1) or via a 2-way screw terminal block (CON2). For the screw terminal input, one terminal is connected to ground while the other is applied to the amplifier stage via a 10kΩ resistor.

When an electret microphone is used, bias current is selected when link LK1 is closed. The 10kΩ bias resistor is connected to a supply that is decoupled from the 11.4V supply via a 1kΩ resistor and a 100µF capacitor. This decoupling prevents supply variations entering the input to the amplifier to cause false triggering.

If the electret microphone is connected via the stereo jack socket input, the electret is connected between the ground terminal (sleeve) and the tip of a mono jack plug. Again, link LK1 is inserted for electret power.

If an electret is not used and signal is applied via the jack socket or screw terminals, the link (LK1) is left disconnected. Stereo signals can be connected via the stereo jack socket and the signal is mixed down to mono using 10kΩ resistors for each channel. This stereo mixing occurs when link LK2 is inserted.

Dynamic microphones do not require bias current; in fact they should not be connected to a circuit providing electret bias, hence the reason for LK1.

A 100nF capacitor couples the mono signal to op amp IC1a. Its non-inverting input, pin 3, is biased from the decoupled supply via two 100kΩ resistors. This sets the ampli-fier output to swing symmetrically about a nominal half-supply voltage. The half supply will vary from about 5.3V to about 5.6V, depending on whether or not an electret microphone is connected.

Diodes D1 and D2 are included to clamp any signal to +0.6V above the decoupled supply and -0.6V (ie, below the 0V rail). They protect the IC1 input if an excessive signal is applied.

IC1a is connected as a non-inverting amplifier with a gain of 2 when VR1 is set to zero ohms and a gain of about 1000 when VR1 is set to its maximum. The actual gain when VR1 is set to a high value is dependent upon the signal frequency

Specifications

Power supply:	12VDC at 50mA
Trigger sensitivity:	Adjustable from 2mV (microphone) to 2V (line)
Maximum signal input:	50V rms
Signal frequency range:	16Hz to >600Hz
Attack time:	10 cycles with signal at threshold voltage (faster attack if signal is above threshold)
Hysteresis:	0.44V at the 2.06V threshold
Delay time:	Adjustable from 100ms to 10s
Electret bias current:	~320µA
Relay contacts (DPDT):	5A (maximum of 50V recommended)

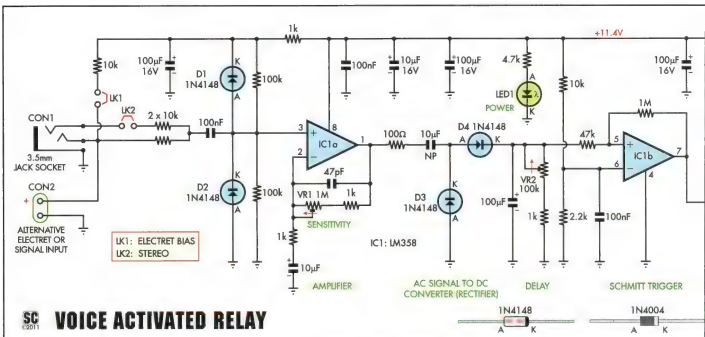


Fig.1: complete circuit diagram of the VOX, or Voice Activated Relay. It's all based on one IC, an LM358, which performs the dual function of signal amplifier and comparator/schmitt trigger. A handful of other components complete the circuit.

and the open- loop gain of the LM358 op amp.

The 47pF capacitor is included to provide a steep roll-off at high frequencies, to ensure IC1 does not oscillate. However, it is the open-loop gain of the amplifier that sets the bandwidth. For example at a gain setting of 100 (when VR1 is 99kΩ), the roll-off caused by the 47pF capacitor is about 34kHz.

Roll-off due to the open-loop gain is at around 6kHz. With VR1 set for a gain of 1000, the 47pF rolls off frequencies above about 3.4kHz. But the open-loop gain begins to roll off beyond about 600Hz.

Low frequency rolloff is set at about 16Hz. This is due to the 1kΩ resistor and 10µF capacitor connected in series to the inverting input.

The output signal from op amp IC1a is fed to a rectifier involving diodes D3 and D4, to convert the AC signal to a DC voltage. As pin 1 swings above its resting position of 5.7V, the 10µF capacitor discharges via diode D4 into the 100µF capacitor at D4's cathode. When pin 1 swings below 5.7V, the 10µF capacitor discharges via D3. The 100µF capacitor then charges with repetitive pulses provided by the 10µF capacitor.

Op amp IC1b is connected as a Schmitt trigger comparator, with the inverting input at pin 6 tied to a voltage divider comprising a 10kΩ and 2.2kΩ resistor across the 11.4V supply. Pin

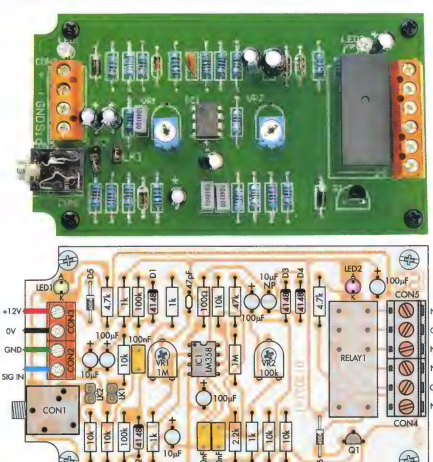
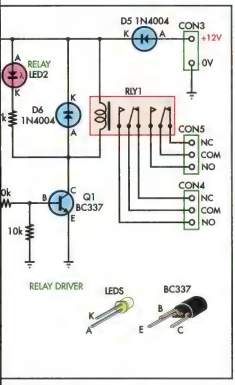


Fig.2: everything mounts on the one PCB, shown here in both diagram and photo form. The only thing "missing" from the PCB is the microphone which must be mounted off the board, as it will "hear" the relay pulling in and releasing and more than likely trigger in error. It can be mounted on a short pair of wires if you wish, or as long away as necessary using a shielded microphone cable.



Parts List – VOX

1 PCB coded 01207111, 106 x 61mm
1 DPDT 12V relay, 5A contacts (Jaycar SY-4052, Altronics S4190C) (RLY1)
1 3.5mm stereo socket PCB-mount (Jaycar PS-0133, Altronics P0092)) (CON1)
2 2-way PCB-mount screw terminals with 5.08mm pin spacing (CON2,CON3)
2 3-way PCB-mount screw terminals with 5.08mm pin spacing (CON4,CON5)
1 electret microphone insert (MIC1) (if required – see text)
1 1MΩ horizontal mount trimpot (Code 105) (VR1)
1 100kΩ horizontal mount trimpot (Code 104) (VR2)
2 2-way pin headers with 2.54mm pin spacing (LK1,LK2)
2 2.54mm jumper shunts
4 M3 tapped spacers (optional)
4 M3 x 6mm screws (optional)
1 length of hookup wire or single cored shielded cable

Semiconductors

1 LM358N dual op amp (IC1)
1 BC337 NPN transistor (Q1)
4 1N4148 switching diode (D1-D4)
1 1N4004 1A diodes (D5,D6)
2 3mm red LEDs, 1 red and 1 green (LED1,LED2)

Capacitors

3 100µF 16V electrolytic
1 10µF Non Polarised (NP) electrolytic
2 10µF 16V electrolytic
3 100nF MKT polyester
1 47pF ceramic

Codes:	µF Value	IEC Code	EIA Code
	0.1µF	100n	104
	NA	47p	47

Resistors (0.25W 1%)

	4-Band Code (1%)	5-Band Code (1%)
1	1MΩ brown black green brown	brown black black yellow brown
2	100kΩ brown black yellow brown	brown black black orange brown
1	47kΩ yellow purple orange brown	yellow purple black red brown
6	10kΩ brown black orange brown	brown black black red brown
2	4.7kΩ yellow purple red brown	yellow purple black brown brown
1	2.2kΩ red red red brown	red red black brown brown
4	1kΩ brown black red brown	brown black black brown brown
1	100Ω brown black brown brown	brown black black black brown

6 sits at about 2.06V and is bypassed with a 100nF capacitor.

IC1b's non-inverting input, pin 5, monitors the voltage across the 100µF capacitor via a 47kΩ resistor. When the 100µF capacitor voltage is below pin 6, IC1b's output at pin 7 is low; close to 0V. When the capacitor voltage rises above pin 6, pin 7 will go high to about +10V. So provided the AC signal fed to rectifier is enough to produce more than 2V across the 100µF capacitor, pin 7 of IC1b will go high and this will turn on transistor Q1 and the associated relay.

Now one of the problems with a trigger circuit like IC1b is that it will not switch cleanly from high to low since a very slight change in the voltage across the 100µF capacitor could mean that it switches back and forth very rapidly. This would have the result that the relay would chatter, ie, also switch on and off very rapidly.

We fix this by adding hysteresis to the circuit, by including the 1MΩ resistor between pin 5 and 7. What now happens is that when the output switches high, it also pulls pin 5 slightly higher, 0.35V higher than the 100µF capacitor voltage. This means that the capacitor has to discharge by this amount before the IC1b will go low again. This stops the relay chatter.

The 100µF capacitor is continually discharged via VR2 and the 1kΩ resistor. So if signal from IC1a is not continuously replenishing the 100µF capacitor, the voltage will drop in level. VR2 sets the delay period from when IC1b is triggered high to when its output goes low in the absence of signal from IC1a.

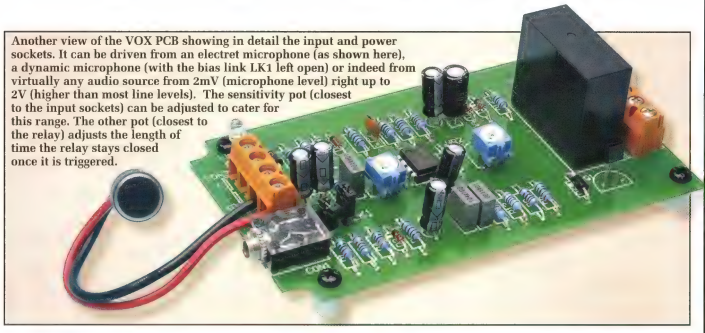
The VOX runs from a 12V supply and diode D5 is included for reverse polarity protection. LED1 indicates when power is present.

Construction

The VOX is assembled on a PCB coded 01207111 and measuring 106 x 61mm. All of the components are mounted on the PCB, apart from the microphone which must not be – it needs to be off the board so that it does not attempt to retrigger the circuit whenever it "hears" the relay switch off.

The PCB is sized to clip into the integral side slots of a UB3 utility box measuring 130 x 68 x 44mm. If you are using this box, make sure the left edge of the PCB is shaped to the correct outline so it fits into the box, clearing the internal corner pillars. That way the 3.5mm socket can pass through the end of the box. It can be filed to shape if necessary, using the PCB outline shape as a guide.

Begin construction by checking the PCB for breaks in tracks or shorts between tracks or pads. Repair if necessary. Check hole sizes for the components and for the corner mounting holes.



Another view of the VOX PCB showing in detail the input and power sockets. It can be driven from an electret microphone (as shown here), a dynamic microphone (with the bias link LK1 left open) or indeed from virtually any audio source from 2mV (microphone level) right up to 2V (higher than most line levels). The sensitivity pot (closest to the input sockets) can be adjusted to cater for this range. The other pot (closest to the relay) adjusts the length of time the relay stays closed once it is triggered.

Assembly can begin by the inserting the resistors. When doing this, use the colour codes in the parts list to help in reading their values. A digital multimeter can also be used to measure each value. Next come the diodes, remembering these must be mounted with the orientation as shown. There are two types of diodes; the smaller 1N4148s are D1-D4 while the larger 1N4004 types are D5 and D6.

IC1 can be soldered directly into the PCB (or you can use a DIP8 socket if you wish). When installing the IC (and socket), take care to orient them correctly. Orientation is with the notch positioned as shown.

Capacitors can be mounted next. The electrolytics must be oriented with the shown polarity except for the NP (non-polarised) type that can mount either way.

Mount the transistors and trimpots VR1 and VR2. VR1 is the 1MΩ trimpot and could be marked with its value or with the coding 105. The 100kΩ VR2 could be marked as 104.

LED1 and LED2 are mounted about 5mm above the PCB. The anode is the longer lead and is placed in the uppermost hole.

The 2-way pin headers for LK1 and LK2 can be mounted now, followed by the 3.5mm socket, the relay and the screw terminals. CON1 and CON2 are 2-way terminals that are first attached by sliding the dovetail sections of each together. Similarly for the CON3 and CON4 terminals, these are slid together before being mounted on the PCB. Make sure the wire entry side face the outside of the PCB.

We mounted the PCB on four 6mm long tapped spacers, held in place with M3 x 6mm screws but this is entirely up to you and your application.

If using an electret microphone, this should be mounted so that it does not touch the PCB and connected via multi-strand hookup wire for short (less than 30mm) leads or using single core shielded cable for longer runs. The shield wire connects to the GND terminal (for the 3.5mm jack plug, the GND is the sleeve). Signal connects to the second screw terminal for the screw terminal input or the tip connection of the 3.5mm jack plug.

For a signal input other than a microphone, apply the signal to either the screw terminals or via a 3.5mm jack plug. One channel connects to the tip terminal and the other channel to the ring terminal.

Link selection depends on whether you are using an electret or dynamic microphone or a mono or stereo signal connection. LK1 should be linked only when the electret microphone is used and removed for a dynamic mic.

LK2 should have a jumper link for a stereo signal. You wouldn't normally have both LK1 and LK2 in position at once but there are stereo electret microphones around so it is possible (though why you'd want to use one in this application is a bit beyond us!).

Apply 12V power and adjust VR1 so that the relay triggers at the required signal level. Similarly, adjust VR2 so that the relay switches off after the desired time period. The delay should be as short as possible but not so short that it drops out while speaking.

If the Voice Activated Relay does not work, first check your soldering to make sure there are no dry joints, solder bridges or dags, etc.

If the visual inspection looks OK, check voltages on the circuit. There should be about 11.4V between pins 4 and 8 of IC1. Pin 3 of IC1 should be around 5.7V to 5.3V. Pin 6 of IC1b should be at about 2V.

Incorrect voltages may be because of incorrect resistor values or a short or open circuit connection. Check that LED 1 lights. Output of IC2 at pin 7 should be near 0V when no signal is applied (or when no sound is detected by the microphone).

With sufficient signal applied, the pin 7 output should go to around 10V, the relay should switch on and LED2 should light. The relay should switch off after the preset time period when there is no signal.

9V operation?

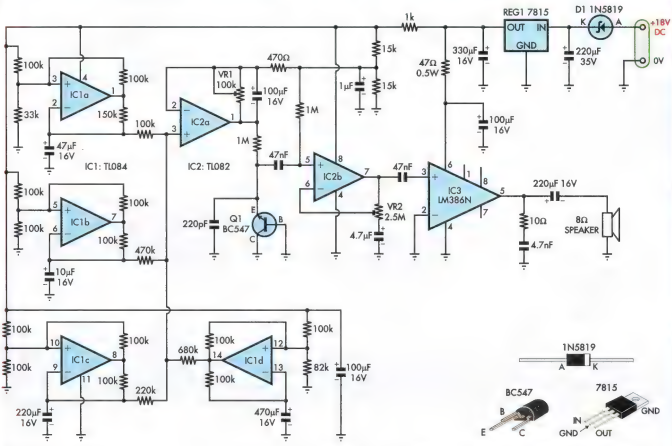
We know we will be asked the question! Some constructors may wish to use the VOX as a stand-alone device – so we'll answer it already!

No, operation from 9V would be quite unreliable, especially if the battery is a bit flat. And the 50mA current draw would put the battery in that state pretty quickly!

Most of the circuit would be fine at 9V but the 12V relay would not be at all happy (if indeed it worked at all). Substituting a 5V relay may be an option, with a resistor in series with the coil but it may not be possible to get one which fits the PCB without modification. SC

CIRCUIT NOTEBOOK

Interesting circuit ideas which we have checked but not built and tested. Contributions will be paid for at standard rates. All submissions should include full name, address & phone number.



Surf sound synthesiser

Many people who live close to the ocean have the benefit of being lulled to sleep by the sound of the surf. This circuit may provide a similar benefit to all those poor unfortunates who don't live near the seaside but who do have the small consolation that they don't have to worry about rust and corrosion in a salty atmosphere.

The circuit consists of four unsynchronised oscillators which are mixed together to modulate a white noise source to simulate the more or less random nature of surf sounds. You won't hear the waves crashing but the ebb and flow of the white noise will help mask other noises which would otherwise disturb your sleep.

The four oscillators are based on four op amps in a TL074 or TL084 quad op amp package (IC1). IC1a, IC1b, IC1c & IC1d are configured as Schmitt trigger oscillators with their operating frequencies defined by the resistor connected between their outputs (pins 1, 7, 8 & 14) and the respective inverting inputs (pins 2, 6, 9 & 13), as well as the electrolytic capacitors connected between these latter pins and 0V.

The result is a triangle waveform at each of the respective inverting inputs and square waves at the same frequencies at the op amp outputs. We don't use the square outputs but instead feed the four triangle waveforms to op amp IC2a which is connected as a mixer. Its output is used to drive and modulate a noise source based on NPN transistor Q1. This is operated with reverse bias across its base-emitter junction and the controlled reverse current is very noisy.

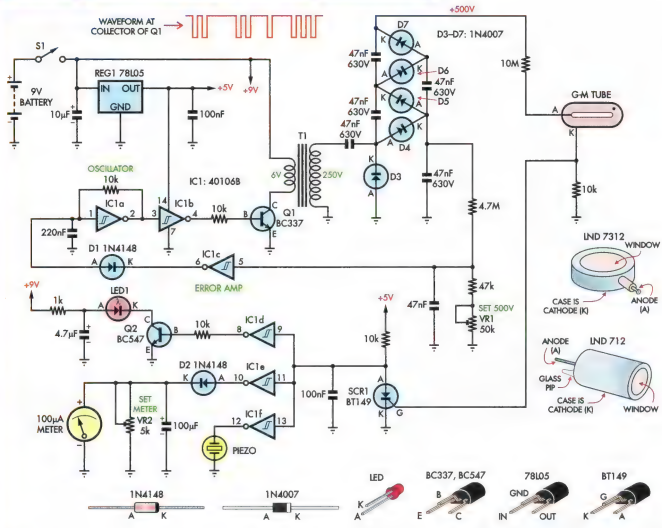
By varying the amount of reverse bias, we vary the amount of white noise produced.

Since the amount of noise produced by the transistor varies markedly between types, the gain of IC2a can be varied over a wide range to produce the optimum output voltage to drive Q1.

From there, the noise signal from the emitter of Q1 is fed via a 47nF capacitor to op amp IC2b which can also have its gain varied over a wide range to drive IC3, an LM386 power amplifier which drives the loudspeaker.

In use, first adjust trimpot VR2 to set the volume level from the loudspeaker, then adjust trimpot VR1 to get the best range of white noise which simulates the surf sounds. Sleep well.

Craig Kendrick Sellen, Pennsylvania, USA. ($50)



Geiger counter uses Cockroft-Walton multiplier

The recent tsunami in Japan and the on-going calamity with the Fukushima nuclear power plant has apparently greatly increased sales of radiation meters, not only in Japan but elsewhere around the world.

This device will allow an estimation of the level of radioactivity, being sensitive enough for background radiation monitoring or to provide an estimation of the level of radioactivity from sample objects such as Thorium gas mantles in LPG lamps.

The circuit is compatible with several Geiger Muller tubes and three types of indication are provided: the good old-fashioned audible click with each discharge, a flashing LED or an analog meter providing a rough average of radiation levels.

A normal background count in New Zealand with the smaller GM LND712 tube is around 30 counts per minute, while the larger and more-sensitive LND7312 pancake tube will count about four times this figure.

Both GM tubes will detect alpha, beta and gamma radiation. Unless the tube is "filtered", there is no way of knowing just what type of radiation is being detected, although a rough guess can be made.

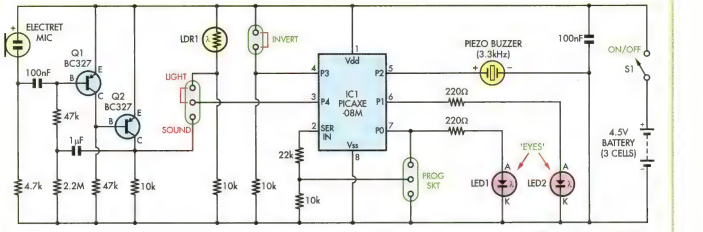
Alpha particles will be stopped by placing a sheet of paper between the tube and the source, Beta particles (electrons) will be stopped with a few layers of aluminium foil and the more lively Gamma rays will need a layer of lead.

The circuit provides a regulated 500V supply for the Geiger Muller tube. This voltage places the tube into its linear operating mode so that a discharge inside the tube will occur when a particle enters through the mica window of the tube and causes the gas to ionise. The very short pulse produced is stretched and used to signal that a discharge has occurred.

The power supply consists of an oscillator and small transistor driving the 6V secondary of a 240VAC mains transformer. The stepped up output of the transformer is fed to a Cockroft-Walton voltage multiplier consisting of diodes D3-D7 and the associated 47nF 630V metallised polyester capacitors.

IC1 is a 40106 Schmitt trigger inverter and IC1a is connected as an oscillator running at several hundred hertz. This is buffered by IC1b and fed to the base of NPN transistor Q1 which then drives the abovementioned transformer.

IC1c acts as an error amplifier to



PICAXEL the electronic cricket

SILICON CHIP has presented two electronic cricket projects: Horace the cricket (August 1990) and his cousin Clifford the cricket (December 1994). Horace only chirped if he heard a noise but otherwise kept mum; Clifford behaved the same, with eyes flashing as well, but only in the dark.

PICAXEL is just as pesky as Clifford but is based on a PICAXE08M microprocessor rather than op amps or a CMOS hex inverter. PICAXEL can respond to either sound (electret microphone) or light (LDR) sensors and can produce a chirp sequence rather than a single chirp.

Transistors Q1 & Q2 amplify the sound from the electret microphone which has bias provided by the 4.7kΩ resistor. Alternatively, ambient light is sensed by the LDR (light dependent resistor) and it produces a low signal in darkness, when its resistance is high. Either the electret or LDR signal is fed to the P4 input of IC1 via the jumper block.

For the electret option, loud sounds will turn Q1 off and Q2 on and the P4 input will switch high for a period set by the 1µF feedback capacitor. The two transistors will then revert to the quiescent state, with Q1 on and Q2 off, ready to react to the next sound. The P4 input of the PICAXE is operated in the A/D converter mode, allowing an accurate mid-rail switching level for both light and sound operation.

Three pins of IC1 are configured as outputs. Outputs P0 and P1 drive the two LEDs, representing PICAXEL's eyes. They light up each time he chirps. The P2 output drives the 3.3kHz piezo buzzer. The program pulses the piezo buzzer in a sequence of chirps, starting with a single 150ms chirp followed by eight short 20ms chirps, then a rest or pause time of two seconds before the next chirp sequence begins.

Normally, PICAXEL will chirp when it is light, remaining quiet when it is dark. To reverse this normal operation, place a jumper on the "invert" pins for the P3 input. He will now chirp when it is dark and remain quiet when it is light. This "invert" jumper should not be used with the "sound" jumper installed because false triggering will occur due to the drop-outs present in all sound sources.

Ian Robertson is this month's winner of a Peak Atlas Test Instrument

The circuit is powered by a 3-cell 4.5V battery pack and includes a standard PICAXE 3-pin programming socket. You could build PICAXEL without any sound input by deleting all the components to the left of the "sound" link.

You can also modify the sound your cricket makes by tweaking the program. Enter different pause times in the chirp routines. For example, try 100 rather than 150 or perhaps use 15 rather than 20. While you are at it, try increasing or decreasing the number of chirps; eg, try six or 10 instead of eight small chirps.

During development of this project I tried a wide range of settings and all sounded like a cricket to me; but perhaps not to another cricket!

Ian Robertson,
Engadine, NSW.

regulate the high voltage fed to the GM tube. A portion of the DC voltage produced at the junction of diodes D4 & D5 is monitored by a voltage divider consisting of the 4.7MΩ and 47kΩ resistors, in combination with trimpot VR1.

When the voltage from D5 is below the positive threshold of IC1c, its output will be high and IC1a will be able to oscillate. Hence, the oscillator will pulse on and off, to maintain the 500V set by VR1.

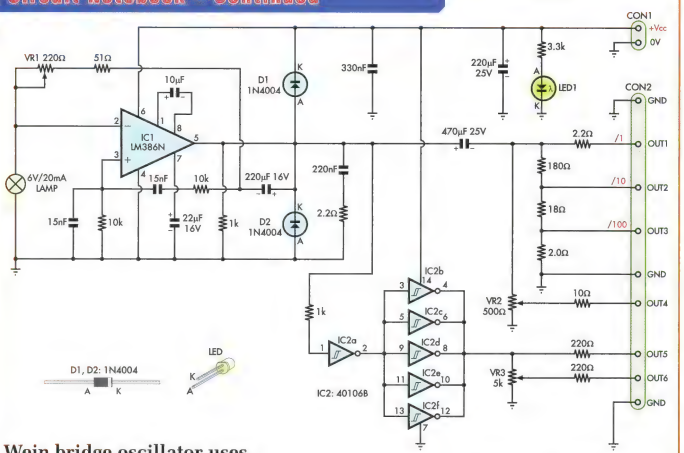
Each time there is a discharge in the GM tube, the resultant current triggers the BT149 SCR which discharges the associated 100nF capacitor and thereby acts as a pulse stretcher to drive the three remaining inverters in IC1. These in turn drive a high-brightness red LED (LED1), a piezo transducer and an analog metering circuit which is based on an old VU meter movement with a scale graduated in counts/minute.

The current drain of the circuit is 10mA and a small 9V battery should run the counter for many hours.

Warning: do not touch the window of the GM tube. These are very fragile and made of very thin mica, to allow the low-energy alpha particles to pass through.

With the LND 712, 200 counts per minute is roughly equivalent to 0.3 micro-seiverts.

Dayle Edwards,
Taylorville, New Zealand. ($70)



Wein bridge oscillator uses an LM386 power amplifier

Most audio oscillators are based on conventional op amp ICs but these are usually intended to drive a load of no less than 600 ohms and cannot deliver any useful power into lower impedance loads. This particular circuit was devised for testing cables, loudspeakers, headphones, transformers, inductors etc where rather more current and voltage is required.

Using the LM386 amplifier IC meets the power requirement and it is connected in a standard Wein bridge oscillator configuration with the operating frequency of 1kHz being set by the components connected between pins 3 & 5. The output amplitude is set to around 8V peak-to-peak by means of the incandescent lamp connected to pin 2 and by trimpot VR1.

The 220nF capacitor and 2.2Ω resistor connected to the output (pin 5) comprise a standard Zobel network to ensure stability of the LM386 and the output is coupled via a 470µF capacitor and 2.2Ω resistor. Diodes D1 & D2 are included to enable the amplifier to safely drive inductive loads if it is overloaded. It will drive any load provided its impedance is more than 4Ω.

A low-power square wave output is provided by the 40106 hex Schmitt trigger inverter. IC2a is connected to the output of the LM386 via a 1kΩ resistor and it "squares up" the 1kHz sinewave. Its output is fed to the inputs of the other five inverters which are connected in parallel to provide a fixed output with relatively low impedance which is defined by the 220Ω resistor and the limited output current capability of each CMOS inverter.

Potentiometer VR3 provides a variable output.

Petre Petrov,
Sofia, Bulgaria. ($50)

Synthetic 5-segment potentiometer

This simple circuit was devised to provide an easier way to 'fine adjust' the output level from my audio signal generator to a specific level. This was quite difficult with the generator's inbuilt output level controls, which consist of just a 50-ohm wirewound pot followed by a couple of switched decade dividers.

I realised that fine adjustment would be much easier if I were to use a multi-turn pot but these are not available from the usual suppliers. So I decided to build up the equivalent of a multi-turn pot, using readily available parts.

The circuit uses a 2-pole 5-position rotary switch (S1), a 500Ω linear pot (VR1), nine 100Ω 1% metal film resistors and a 100Ω multi-turn trimpot (VR2). These parts are arranged in a circuit a little like the traditional multi-stage stepped potentiometer.

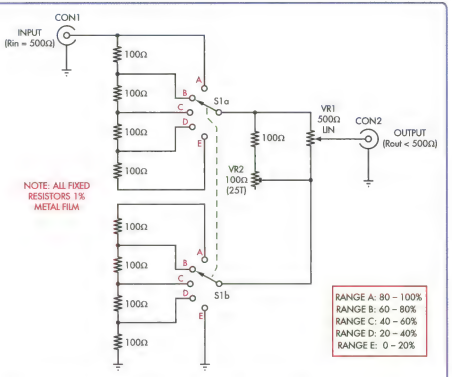
Basically VR2 and one of the 100Ω resistors are connected in parallel with the 500Ω element of VR1, so that by careful adjustment of VR2 the

total resistance connected between the poles of S1 is "padded" down to exactly 100Ω. Then depending on the particular position to which S1 is set, this "100Ω pot" effectively becomes one of the segments in a 5-segment voltage divider, connected between the input (CON1) and ground.

For example, with S1 switched to the "B" position as shown, the output pot forms the second-highest divider segment – with one 100Ω fixed resistor above it and three same-value resistors below it. As a result, the pot's adjustment range varies between 60% and 80% of the input voltage.

If switch S1 is set to the "D" position instead, the output pot then forms the second-lowest divider segment – with three 100Ω fixed resistors above it and only one below it. So it now has an adjustment range of 20-40% of the input. And so on, with the effective adjustment range of the five switch positions shown in the small table.

By the way, the reason for using VR2 and its series 100Ω resistor to "pad" the effective resistance of VR1 down to 100Ω is to ensure that the five adjustment ranges are contiguous, with neither gaps between them nor overlapping at their maximums and minimums. This only happens when the effective pot resistance is 100Ω, matching the fixed resistors in the divider.



The complete circuit was housed inside a small aluminium box measuring 111 x 60 x 30mm, to provide it with shielding. The input and output connectors were panel-mount BNC sockets, each mounted on one end of the box.

Switch S1 and trimpot VR1 were mounted in the bottom of the box, which became the top when the box was inverted for use.

Jim Rowe,
Silicon Chip.

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Vintage Radio

By Maurie Findlay, MIE Aust, VK2PW

The Hotpoint Bandmaster J35DE console radio

Over the next few months, veteran radio designer Maurie Findlay will go through the process of restoring a good "1940s wireless" to its original performance – and for those who are interested, he describes how to make it perform even better than new. The radio to be restored is a Hotpoint Bandmaster which was made in console (J35DE) and table (T55DE) models. Maurie takes up the story . . .

The Hotpoint Bandmaster J35DE was a 1940s console radio that offered quite good performance in its day. This example is still in good condition, although the grille cloth needs replacing and the cabinet requires work.

WHILE THERE were many run-of-the-mill radios produced during the valve era, those with better performance were considerably more expensive and are now hard to come by. And while the sets made by AWA were highly regarded, those branded Hotpoint would these days hardly rate a second glance by vintage radio collectors. However, they would be missing out.

Hotpoint-branded radios were made by AWA Pty Ltd (Amalgamated Wireless Australasia), Australia's biggest electronics company in the 1940s. Which just goes to show that "badge engineering" was not confined to the automotive industry.

The Hotpoint Bandmaster T55DE/J35DE is a 5-valve radio offering AM broadcast band and shortwave reception, with provision for a pick-up to play records. The chassis may also have been the basis for radiograms made by AWA at the time.

The Hotpoint J35DE/T55DE chassis was virtually identical to that in the AWA 721-C console radio and the 618-T mantle (or table) radio. A set of this general type, in good order, will have a reserve of performance for local broadcast stations and will receive the stronger shortwave stations.

With care and patience, the valves and other components can be tested, replaced if necessary and the set realigned for best performance using no more than a multimeter. That said, the meter needs to be a modern digital multimeter.

Multi-range meters available at the time the Hotpoint was designed mostly used a moving coil meter which required a current of 1mA for full-scale

deflection (FSD). Such a meter would give readings very much in error in many radio circuits because of the high resistances involved.

For example, take a look at the circuit diagram of the radio featured in this article. At valve V3's plate, it would read about one third of the actual voltage on the 100V scale. That's because the relatively low impedance of a moving coil multimeter loads down the voltage when attempting to measure such a circuit.

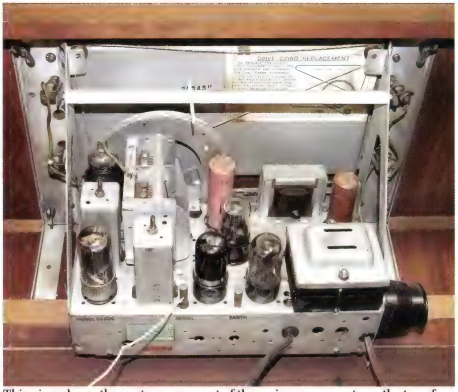
By contrast, a modern digital multimeter has an input resistance of 10MΩ (100 times greater) and would have very little effect on the voltage.

Apart from a good digital multimeter (DMM), you will need spare parts, small hand tools and most important of all, some skill with a soldering iron. Still, if you have assembled a typical PCB, you should have no trouble soldering parts in an old radio chassis. However, you will need a bigger soldering iron to do some of the work.

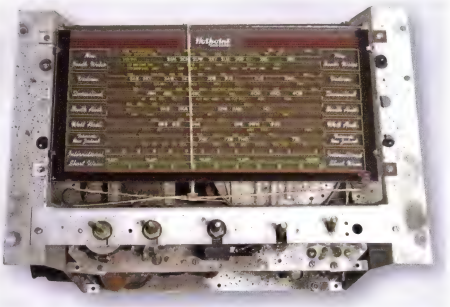
The Hotpoint T55DE is typical of 5-valve sets made in the valve era. It used good quality components which were operated conservatively and offered what most owners wanted: reliable reception of the local broadcast stations.

More elaborate receivers, for use in remote areas, would have had an extra stage of amplification between the aerial and the mixer stage. For those needing high volume, a more elaborate audio system, perhaps using push-pull valves, would be prescribed. In addition, shortwave reception could be improved by incorporating a bandspread system so that particular frequencies can be tuned more easily, while an extra RF amplifier stage is also a big advantage at the higher frequencies. And so it goes on.

The aim of this article and the one that follows is to give enthusiasts, with only a basic knowledge of radio, a systematic means of restoring vintage receivers to full performance. A particular set has been chosen in order to avoid a string of generalities which could easily have been confusing. I have redrawn the manufacturer's circuit diagram, with component values marked, to avoid the need to refer to the parts list when studying the diagram.



This view shows the neat arrangement of the major components on the top of the chassis. A label on the dial backing plate shows the drive cord arrangement.



The old Hotpoint featured a rather elaborate glass dial which carried markings for the Australian states, New Zealand and the international shortwave band.

Circuit details

Let's start by going through the various stages of the Hotpoint T55DE. Fig.1 shows the circuit details.

Valve V1 is the mixer, sometimes called the 1st detector, and is a 6J8-G. It takes the signal from the aerial (antenna) and converts it to an intermediate frequency which makes it easier to obtain the amplification and selectivity required.

The 6J8-G has a special "heptode" construction which consists of a fine helix grid close to the cathode, a screen grid surrounding that and yet another screen grid followed by the suppressor grid and then the plate. In between the two screen grids is another grid which is connected to the grid of a separate triode element.

This sounds complicated but this construction allows the local oscil-

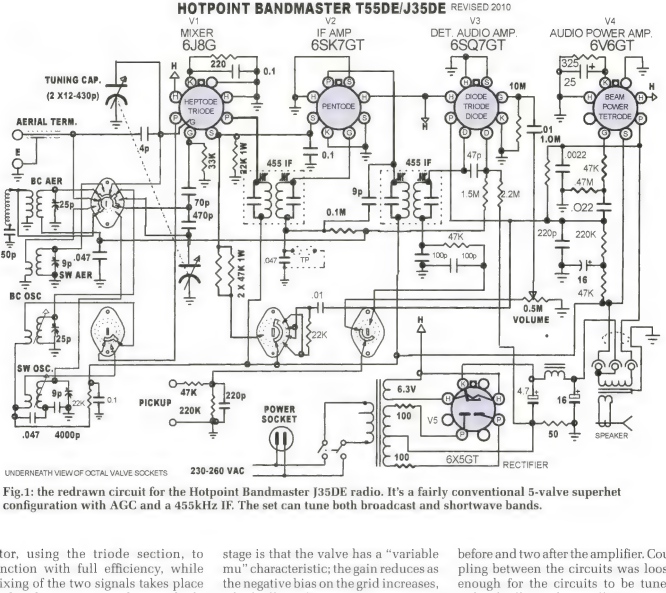


Fig.1: the redrawn circuit for the Hotpoint Bandmaster J35DE radio. It's a fairly conventional 5-valve superhet configuration with AGC and a 455kHz IF. The set can tune both broadcast and shortwave bands.

lator, using the triode section, to function with full efficiency, while mixing of the two signals takes place in the electron stream from cathode to plate. Several frequencies appear at the plate but the one we want, the difference between the signal and the higher oscillator frequency, is selected by the 455kHz tuned circuit.

6J8-Gs cost more to manufacture than other valves designed to do the same job but this valve worked better than most, particularly on the short-wave bands. It was often used in quality receivers manufactured at the time.

The next stage, V2, uses a 6SK7-GT pentode. The internal shielding between the control grid and the plate is provided by the usual screen and suppressor and the valve is able to amplify in a stable fashion. Other valves, such as the 6U7-G, available at the time, could have done the job equally well.

An important requirement for this stage is that the valve has a "variable mu" characteristic; the gain reduces as the negative bias on the grid increases, which allows for automatic gain control (AGC).

An interesting point about the design of the Hotpoint circuit is that AGC control is applied to both the 6J8-G and the 6SK7-GT on the broadcast band but only to the 6SK7-GT on shortwave. This allows greater amplification for the weaker shortwave signals.

Another special design point is the filter in the broadcast band aerial circuit. A 50pF capacitor in series with a high-Q inductor forms a series tuned circuit at 455kHz, effectively shorting out the receiver input at that frequency. Not many designers would have considered this necessary, because 455kHz is kept clear of high-power transmitters.

As was conventional at the time, this set has four circuits tuned to the intermediate frequency of 455kHz, two before and two after the amplifier. Coupling between the circuits was loose enough for the circuits to be tuned individually without affecting each other. The resultant selectivity caused attenuation of the higher sidebands and hence a reduction in the higher frequency audio. At the time, few designers would have incorporated a bandpass arrangement. People seemed to think that radios should have a "mellow" tone.

Detection & AGC

The next valve, V3, a 6SQ7-GT, incorporates two diodes and a triode. It recovers the audio from the intermediate (IF) signal, provides the automatic gain control and amplifies the recovered audio signal.

Other valve types capable of doing the same job were available at the time. For example, a pentode double-diode could have been chosen for higher gain. But the triode provides a reserve

of gain anyway, with a very simple circuit. The small amount of negative bias required is obtained from a high-value resistor in the grid circuit (10MΩ).

The diode connected to pin 5 of V3 rectifies the 455kHz signal from the IF transformer and the recovered audio signal appears at the lower end of that transformer. At this point, the audio is mixed with the 455kHz IF signal and a filter, consisting of a 47kΩ resistor and two 100pF capacitors, removes this 455kHz component. With the function switch in the "radio" position, the recovered audio appears across the 500kΩ (0.5MΩ) volume control potentiometer.

AGC is developed by the diode connected to pin 4 of V3. However, pin 4 is returned to a voltage that's negative with respect to the cathode via a 2.2MΩ resistor and therefore does not start developing an AGC voltage until a certain signal level is reached. This is "delayed AGC" and ensures that maximum gain is available for very weak signals.

Output stage

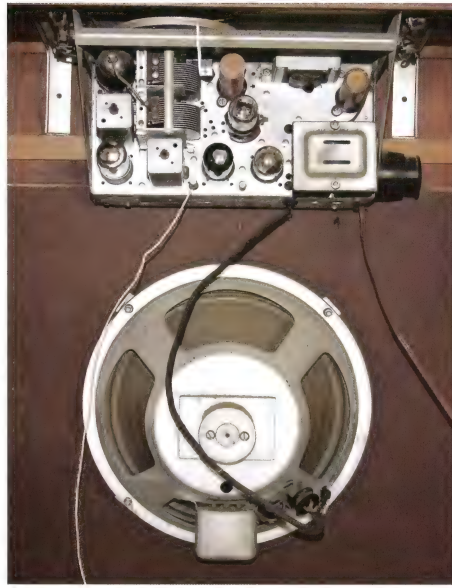
V4, the audio output valve, amplifies the signal further and provides power to drive the loudspeaker. It is a 6V6-GT and was the best choice for the job at the time this set was designed.

In this set, it is operated with a cathode bias resistor that's slightly larger in value than usual. This reduces the power dissipation and audio output of the valve but would make for longer life. The optimum load resistance with the higher bias resistor would be higher than the usual 5kΩ and is probably somewhere around 7kΩ.

Design fault

This circuit has a serious design fault concerning the arrangement for connecting the speaker. The output transformer is mounted on the back of the speaker and is connected to the output valve via a plug and socket arrangement on the chassis. As a result, if the set were to be accidentally switched on without speaker connected, the 6V6-GT screen current would be very high and this would probably ruin the valve.

A better arrangement would be to have the speaker transformer permanently mounted on the chassis and the voice-coil leads extended. Alternatively, a solution such as that described on page 91 of the August 2010 issue of Silicon Chip, for an Airzone 612 console radio, could be adopted. This is what we eventually did with this Hotpoint set.



The chassis mounts vertically inside the cabinet, so that the glass dial and control shafts face upwards. Note that the output transformer is mounted on the speaker frame. This means that the 6V6-GT output valve could be destroyed if the speaker cable is disconnected from the chassis while power is applied.

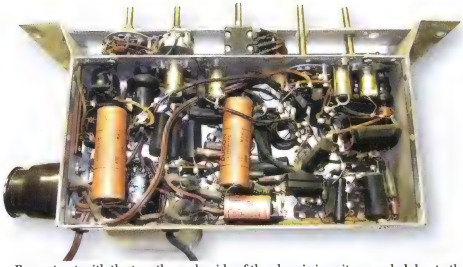
Power supply

A power transformer and rectifier valve, V5, are used to derive the 240V DC high-tension supply for the amplifying valves. However, the usual approach has not been taken. V5 is a 6X5-GT and this valve has special insulation, designed to withstand the high voltage between the cathode and the 6.3V filament. The 6.3V heater winding on the transformer also supplies the other valve filaments and is effectively at chassis potential.

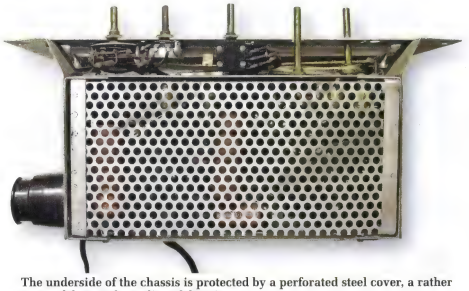
The alternative approach, and the one mostly used in sets at this time, was to use a 5Y3-GT rectifier which has directly-heated cathode supplied from a separate 5V heater winding. This could then "float" at the HT voltage which could be anywhere from 100-300V or more, depending on the circuit requirements.

The 100Ω resistors in each plate circuit of V5 are provided to limit the peak current. The 8μF capacitor connected to V5's cathode also affects the peak current and hence the life of the valve. It should not be replaced with a higher value.

To complete the circuit description, note the function switch which allows the set to be switched for radio or record pick-up operation. There are



By contrast with the top, the underside of the chassis is quite crowded due to the bulky old-style components used. Note the primitive technique used to anchor the power and speaker cables, ie, by tying knots in them.



The underside of the chassis is protected by a perforated steel cover, a rather unusual feature for radios of that time.

tone control positions for both radio and pick-up. In the pick-up position, the screen supply to V1 and V2 is disconnected so that "play-through" from the radio stage, due to stray coupling, is eliminated.

The pick-up input was designed to accept the high-output signals from the crystal (piezoelectric) pick-up cartridges used in the 1940s with 78 RPM records. Not every restorer will want to bring this back to life! In addition, the treble cut applied for radio listening is probably too severe for modern ears and could be reduced by choosing a smaller value for the associated .01μF capacitor.

A power socket for a turntable motor is mounted on the chassis and is alive even with the radio switched off. When replacing the power cord, we used the socket as a convenient termination. However, there is a safety issue here in that the metal terminations in the socket are close to the metal surface on which the socket is mounted. If the bare wires are not pushed right into terminations, there is the possibility of them touching the metal chassis with disastrous results.

Such a socket would definitely not meet approval today.

Preferred value components

In the original service manual for the Hotpoint Bandmaster J35DE, all the passive components, ie, resistors and capacitors, are in "non-preferred" values. For example, one resistor is specified as 2.5MΩ while others are marked 1.6MΩ, 50kΩ, 32kΩ, 25kΩ and 20kΩ. In the capacitor list, there is a 50pF unit, a 70pF (actually μμF) unit, some .05μF units and so on.

This is because this set was made before the introduction of the "preferred value" system, which is now universally used for small components.

With preferred value numbering, a designer can adjust a circuit value to a desired order of accuracy while stocking the minimum number of components. The numbers in the ratios 10, 15, 22, 33, 47, 68 and 100 would be stocked by a design laboratory over most of the range, except for very small and very large values.

On the other hand, for very critical circuitry, a designer may need to stock values in finer increments such as 10, 11, 12, 13, 15, 16, 18, 20, 22, 24, 27, 30, 33, 36, 39, 43, 47, 51, 56, 62, 68, 75, 82, 91 and 100. However, extended over the decades, this could involve a huge number of components.

So what do we do about, say, replacing the 50kΩ resistor in the grid circuit of the 6V6-GT output valve? You cannot buy a 50kΩ resistor at your usual supply store. The answer is that the exact value is not critical and a 47kΩ resistor will do the job perfectly well.

This also applies to most of the other components in the radio. The 2.5MΩ resistor could be replaced with 2.2MΩ, the 1.6MΩ with 1.5MΩ and so on. In addition, the .0025μF capacitor from the plate of V4 to ground can be replaced with a .0022μF capacitor with negligible effect on the way the radio works.

With this in mind, the circuit presented in this article has been redrawn with "preferred values" for most of the passive components. There are, however, some components where accuracy must be maintained.

The 4000pF (4nF) capacitor in the shortwave oscillator circuit is an example. It modifies the tracking of the oscillator frequency to give the desired tuning range. The same applies to the capacitors in the 455kHz IF coils (unmarked).

Next month

Next month's article will describe the practical side of getting the Hotpoint Bandmaster into operation. It is now 60 or more years since the set was manufactured and that meant that a great deal more than defective valves had to be considered. Many capacitors, resistors and even the wiring had deteriorated badly. SC

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Recharging Apple USB devices

I can't quite fathom how a USB port can provide the biasing conditions for a variety of devices, assuming that these iPODs can be charged from a normal PC USB port. I have an Apple Shuffle and a Dick Smith MP3 player. How do I know what biasing is required? (E. J., Otago, Tas).

● The reason that biasing is required for iPods to charge is that when the iPod is plugged into a computer, it communicates with the computer and checks that it can draw 500mA first. According to the USB standard, unconfigured devices are not allowed to draw more than 100mA.

Since there is no computer or microcontroller in the USB charger for Cars & Bikes (SILICON CHIP, May 2010) an iPod can not communicate with it and so can not request the full 500mA. The biasing resistors tell the device that it is connected to a charger and it's allowed to draw more power without having to talk to a computer.

This is a common problem and unfortunately each manufacturer has addressed it in a different way (and in the case of Apple, a different solution for different devices).

The USB3 standard provides a way to make third-party chargers work with any USB device but unfortunately few devices have adopted it yet.

You may find that the Dick Smith MP3 player will charge without any biasing. Some devices skip the configuration process and just draw power from the port.

We don't know what bias voltages an iPod Shuffle needs but if it doesn't charge with D+ and D- unconnected then try shorting those lines together (with a solder bridge). That is the new USB3 method for detecting a charger.

If that doesn't work, try the scheme in Fig.8 on page 72 of the May 2010 issue. One of these two approaches should do the trick. At least one report on the internet suggests that this scheme (or one very similar to it) works with 2nd generation iPod shuffles. However we have not tried it so we can't guarantee that it will work.

Soft-starter wanted for switchmode supplies

Have you produced an article or project for "soft-start" switching 230VAC to transformers and computers? I have a problem occasionally when switching on the power to the power board that supplies the above equipment. It doesn't happen every time but sometimes I see a spark coming from the power point switch at switch on. The total wattage of the devices connected to the power board is only about 450W, so they should be within the 10A rated capacity of the power point switch.

My feeling is that there is an inductive and capacitive load from the conventional wirewound type transformer/s that power the modem etc that's causing this. The power point has been replaced with a new one and I am still experiencing this problem which will eventually burn out the switch contacts again.

What is needed is a "soft start zero current" device to place in front of the power board and after the power point that will eliminate the sudden rush of current at switch on. If such a device has not been produced as a project it could be considered for a future project for your magazine as I am unable to buy anything commercially from electrical suppliers that will give a "soft start" at switch on. Any suggestions that you could offer would be appreciated in solving my dilemma. (B. S., Warners, Bay, NSW).

● Your dilemma is very common. In fact, we think that virtually every household has a similar situation in which the in-rush current to electronic appliances can not only burn out the switch contacts in typical power points but depending on the number of appliances being switched, can also

On Modifying CD-ROM Motors For Higher Power

I'm interested in electric models, mainly airplanes, and have been reading with interest on a few websites about using old CD-ROM drive motors to make brushless airplane motors. This involves re-winding the stator and replacing the magnets to get sufficient power. What are the chances of your techies coming up with a brushless speed controller?

One which can have a range of power outputs by varying output components would be good, however there is a lot of interest in 36-inch wingspan models such as those designed by Peter Rake in the UK. These are suitable for a brushed Speed 400 electric motor, so a speed controller which would suit an equivalent power brushless motor would be great. I'm part way through the construction of a 36-inch Sopwith Pup and am getting to the stage where a decision on the motor etc is imminent. (B. L., via email).

● We have serious doubts whether CD-ROM drive motors could be modified to produce anywhere near enough power for a sizeable model aircraft. Realistically, for the sort of aircraft you are considering you would need a motor capable of many hundreds of watts, or perhaps up to 1HP or more. A modified CD-ROM motor is highly unlikely to be capable of even a fraction of that.

Secondly, we do not have plans to do a brushless motor controller. There are too many variables to cater for and nor do we have RC modellers on tap to do the considerable testing which would be required.

lead to nuisance tripping of circuit breakers in switchboards.

In fact, we have a similar scenario in the SILICON CHIP offices where some desks have a typical desktop computer driving two monitors and other ancillary equipment, all with switchmode power supplies. Just as in your situation, the total rated power of the appliances is probably quite modest at maybe less than 400W but the initial inrush current over the first few cycles of the 50Hz 230VAC waveform can be very large, perhaps 30A or more.

One way to reduce the problem is to avoid switching all the appliances on simultaneously at the power point. Switch on the computer first, followed by the first video monitor and so on.

But we realise that few people will want to go to that much trouble. In fact, we have just such a soft-start module in the pipeline and it should be published within the next few months.

Increasing door strike time in RFID module

I built the RFID Security Module (SILICON CHIP, June 2004) which was designed by Peter Smith. How can I change the time the door strike output stays on for (ie, when a valid tag is presented) from a few seconds to a few minutes? (J. H., Bankstown, NSW).

- The door strike on-period can be extended by changing transistor Q3 to an IRF540N N-channel Mosfet. The Mosfet is installed with the same orientation as the transistor, with the Mosfet's gate in place of the transistor's

Disconnecting Loudspeakers When Headphones Are Plugged In

I have a question regarding the Loudspeaker Protector and Muting Module described in the July 2007.

This project uses NO (normally open) contacts for the thermostat. How can it be converted to make the contacts NC so that it can be used to disconnect the loudspeakers using the NC contacts in a loudspeaker socket, when a set of headphones is plugged in? This is the approach you took in the Ultra-LD 100W Stereo Amplifier of November & December 2001 and January 2002. I understand why you might not do it for the Class-A amplifier but it might be useful for a lesser unit such as my LM3886 amplifier. (I. F., via email).

- There are several approaches to using the NC contacts of a headphone socket to disconnect the loudspeakers when the headphones are plugged in. For example, you could wire the NC switch contact in place of the 0Ω link for R2 or it could be placed in series with the 100Ω resistor between the collector of transistor Q1 and the base of Q2.

In the latter case, when the headphone contact opens (ie, when the headphones are plugged in), transistor Q2 switches on (after a short delay to charge the 470nF capacitor via the 100kΩ resistor at Q2's base) to ultimately prevent the relay from being driven via Q3 and Q4.

Note that the headphone socket would need to have an isolated switch contact (eg, Jaycar PS0184 or Altronics P0074). Alternatively, the NO contact for the DPDT stereo insulated switch in the headphone socket could be used in parallel with the NO thermostat contact.

How To Measure Subsonic Sounds From Wind Farms

Has SILICON CHIP ever described a circuit to measure both the frequency and energy of infrasound? We are trying to measure the noise generated by wind farms due to serious concerns with the distress that they can cause to people living in the near vicinity.

It is clear that a relatively cheap meter of some sort is needed to perform in-field measurements in the sub-audible range to test the various theories. (P. K., Mittagong, NSW).

● We have had previous discussions with an acoustics consultant on this topic and he remarked that one of the mechanisms by which subsonic vibration becomes audible is that it rattles window panes and excites ceilings, walls and floors at their own resonances which then amplifies the effect.

By the way, the infrasound is produced each time the turbine blades pass the tower. It is an interference effect. It should be possible to calculate the frequency by simple observation of the number of times the blades rotate in one minute – and then do the calculations.

We have not published an infrasonic meter as such but it would not be a big job to modify one our of previous sound level meter designs so that it has a response down to 1Hz or below. Ideally, you would want a readout of frequency as well.

We published a sound level meter back in the December 1996 issue of SILICON CHIP. It was designed to be used with an external DMM.

We have tried using a couple of standard sound level meters for such measurements and they also have an analog output which could be connected to an oscilloscope or frequency meter. However, we found it doesn't work as the sound level meter outputs have no response to infrasonic signals.

However, we have tried measuring infrasonic pulses (produced by partially opening and closing a door) with the high-performance microphone preamplifier featured in the September 2010 issue (it has a usable response to below 1Hz). To observe the infrasonic signal, you need a digital scope with a slow horizontal sweep speed at around 500ms/div.

base and the drain and source in place of the collector and emitter.

The 1kΩ resistor at pin 9 of IC1 should be lifted and a 1N4148 diode placed in series with this 1kΩ resistor, with the anode at the pin 9 end (the anode end is the end opposite the stripe [K] end of the diode). A 10MΩ resistor should then be connected between the Mosfet's gate and source.

In addition, a 220µF capacitor must be connected between the gate and source (negative to the source).

In this way when the door strike is to be activated, the high output at pin 9 of IC1 would charge the 220µF capacitor via the diode and 1kΩ resistor. This would switch on the Mosfet to power the door strike. When the output at pin 9 of IC1 goes low, the diode is reverse biased and the capacitor discharges via the 10MΩ resistor. When the voltage across the capacitor drops, the Mosfet switches off.

The extra time would be 220 seconds or about three minutes. Change the capacitor value to set the time.

Amplifier slew rate is generally unimportant

Please can you tell me what the slew rate is of the Studio 350 power amplifier module (SILICON CHIP, January & February 2004). (S. W., Stowmarket, UK).

● We did not publish data on the slew rate or gain bandwidth for this amplifier however we did publish a full power square wave, captured with an oscilloscope. Estimating the slope of the vertical edges on that square wave, the slew rate into 8-ohm loads is somewhere in the region of 20-25V/µs. It could possibly be as high as 50V/µs.

An audio amplifier's slew rate can matter to performance but if the amplifier is properly designed, it is not usually critical.

The reason is that most audio amplifiers use dominant-pole compensation (in the form of a Miller capacitor in the "Voltage Amplification Stage") in order to avoid high-frequency oscillations. This capacitor rolls off the open loop gain at higher frequencies. It also limits the slew rate.

If an amplifier has excessive compensation (eg, due to inherent instabilities in the design) then it might have a low enough open-loop gain at high frequencies such that the negative feedback no longer works to cancel

WARNING!

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Readers are warned that high voltage wiring should be carried out according to the instructions in the articles. When working on these projects use extreme care to ensure that you do not accidentally come into contact with mains AC voltages or high voltage DC. If you are not confident about working with projects employing mains voltages or other high voltages, you are advised not to attempt work on them. Silicon Chip Publications Pty Ltd disclaims any liability for damages should anyone be killed or injured while working on a project or circuit described in any issue of SILICON CHIP magazine.

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Next month in Silicon Chip: August 2011

3D Printing

Ever want to make your own plastic prototypes of scale models, unusual hardware items or whatever? You would need a 3D printer wouldn't you? But these are still horrendously expensive, aren't they? Well actually, no and we review a 3D printer which is affordable for most businesses.

Inclinometer

That's a fancy name for a digital spirit level. And why would you want such a thing? Well a spirit level will tell you if a surface is horizontal or vertical but if it is somewhere in between, it won't tell you the slope in degrees. Our inclinometer will. It uses a 3-axis accelerometer chip and a microcontroller (inevitably) to drive a 4-digit LED display.

Electronic Stethoscope

Want to check out your heartbeat or trace some odd sounds in a car engine? This electronic stethoscope will do the job and you can listen on headphones or a loudspeaker. It has switchable frequency shaping in four bands so you can hone in on sounds which would otherwise be masked out.

Ultra-LD Mk.3 Amplifier Module

The second article on this ultra-high-performance amplifier will detail its construction and set-up. It will also provide some more details on its phenomenal performance.

Note: these features are in the the process of preparation for publication and barring unforeseen circumstances, will be in the issue.

ON-SALE: Wednesday, 27th July 2011

distortion. This would also result in a low slew rate, hence low slew rate can be an indicator of poor performance.

However, if you have access to graphs of THD+N vs frequency, rather than using the slew rate as a means to assess the high-frequency distortion performance, you can simply look at the upper end of the graph and note how fast distortion rises with frequency. We publish these graphs for virtually all our designs as well as THD+N vs power graphs.

We suggest that these graphs are the best means of determining whether an amplifier will sound good (in the sense of "clean"; ie, with no added harmonics to muddy the sound). We usually consider the THD+N figures for 1kHz and 10kHz or 20kHz as a way to estimate performance. Is it typical for the distortion at 10kHz to be around 10 times that at 1kHz.

If you need a lot of power then the Studio 350 amplifier has very good performance, as stated in the article. Distortion is low, as is noise. However if you are happy with 135W into 8Ω or 200W into 4Ω (enough power to generate a lot of sound unless your speakers are incredibly inefficient) then take a look at the new Ultra-LD Mk.3. This has even lower distortion and is more compact. It also runs off lower voltages, simplifying the power supply.

As a comparison, the Studio 350 has THD+N figures of 0.002% (1kHz) and 0.02% (10kHz) while our updated Ultra-LD Mk.3 figures are 0.0006% (1kHz) and 0.0027% (10kHz). Not only does the latter have less distortion overall but the rise in distortion at higher frequencies is also much less.

Tuning the Theremin Mk.2

I have built the new improved Theremin Mk.2 according to the project published in Silicon Chip, March 2009. Unfortunately, it is not working. I am an experienced electronic builder and took care of all the details, including the correction of the errata which I found on your website. So far, I cannot make the thing work.

First of all there is no sound. I suspect there is a problem somewhere in the volume control section. The volume oscillator is working but I am not able to do the volume alignment according to the directions published in the project. There is no voltage between TP GND and TP2, whatever I do with T4's slug.

According to the written directions, this voltage should be set to 2.5V. (M. F., Brasilia, Brazil).

- The volume tuning must be done according to the procedure described on page 40 of the March 2009 issue under the heading "Volume Alignment". You need to be able to get 2.5V at TP2 and 7V at TP3 before any sound will be heard. If adjustment of T4 does not provide any change in level at TP2, then try re-positioning the slug in T3 and readjust T4 again. No voltage at TP2 could mean that there is no oscillator signal applied to Q4 or that Q4's T4 slope detection is not working.

An oscilloscope would help in tracing the signal through to diode D6's anode. Otherwise check that the parts are correctly placed and make sure that there is no short circuit between D6's cathode (K) and ground.

Check also that both D6 and the 2.2µF capacitor at D6's cathode are orientated correctly and that D6 is still OK. SC

Notes & Errata

USB Recording/Playback Interface, June 2011: ideally the XLR connectors for the microphone inputs should be female, in line with the usual convention.

Female XLR connectors can be fitted to the front panel and the connections between pins 3 & 1 of each connector swapped over between the connector's rear lugs and the pads on the PCB – instead of passing straight down. This can be done quite easily if short lengths of insulated hook-up wire are used to make these connections, thereby ensuring that there will be no accidental shorts.

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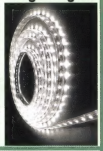

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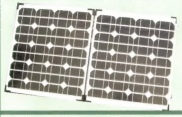

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Includes 5 piece 8mm turning tool set

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- Head tilts ±45° both directions
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  6-30 x 2mm

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- 1/8" split point centre
- 1-13mm range

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- 1/8" split point centre
- 1/16 - 1/2" range

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